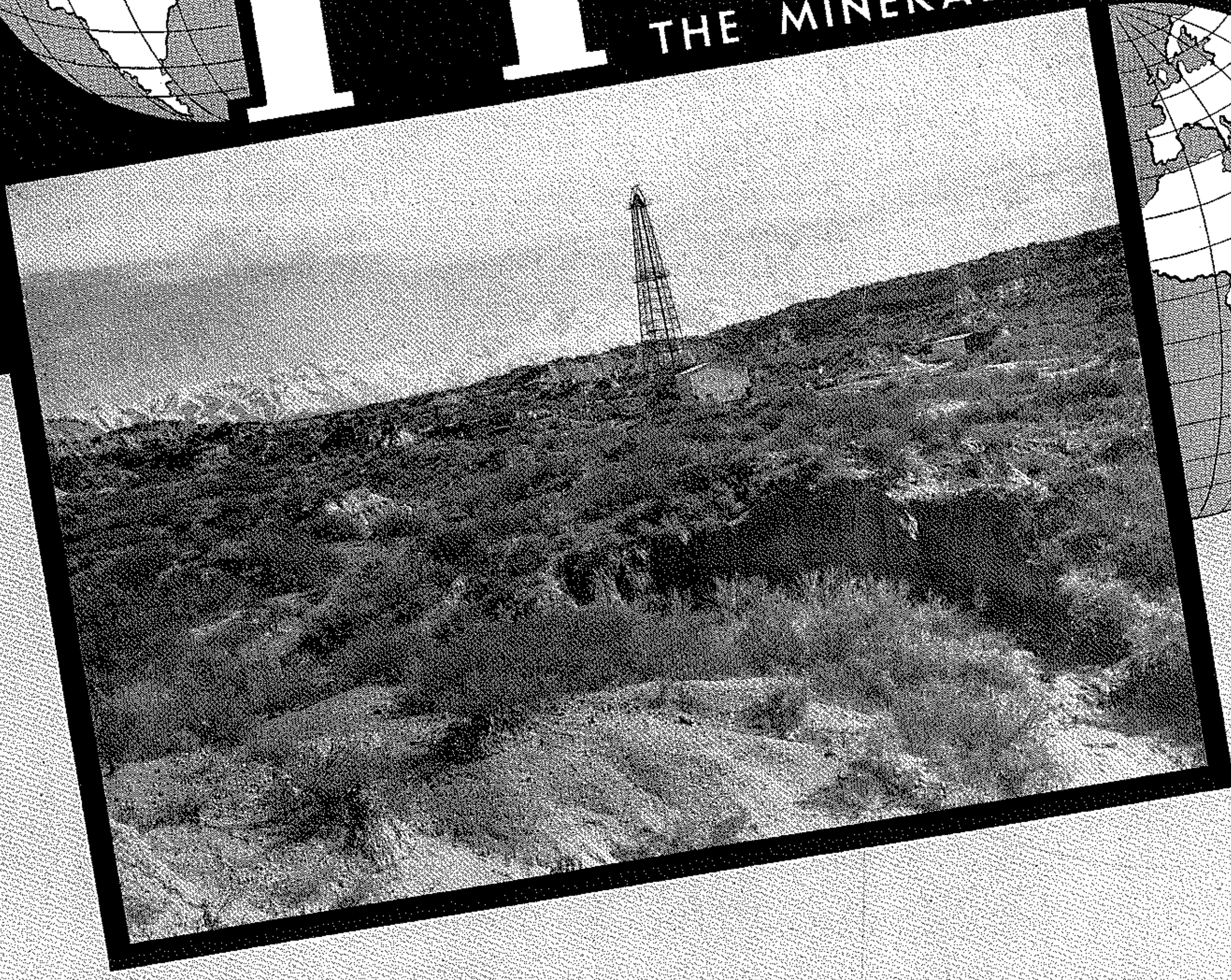
THE MINES MAGAZINE

AROUND THE WORLD WITH THE MINERAL INDUSTRIES



FIFTH ANNUAL PETROLEUM EDITION

PRICE ONE DOLLAR

AUGUST · 1940

VOLUME XXX NO. 8

PERSONAL NOTES

Lewis D. Anderson, '39, is now employed by the Miami Copper Company and is being addressed at his residence, 400-B Pinal Avenue, Miami, Arizona.

S. J. Artese, '30, Chemical Engineer for the Shell Oil Company, has a change of address to 1449 Brown Street, Martinez, Calif.

Robert Barney, '35, who has been associated with the National Fuse & Powder Company in Denver for the past several years, has entered the U. S. Army and is now being addressed, Lieutenant Robert F. Barney, 2nd Engineers Battalion, Fort Sam Houston, Texas.

Frank R. Blood, Ex-'34, received degree, Doctor of Philosophy in Biological Chemistry, from the University of Michigan in June and has accepted a position with E. I. duPont de Nemours & Company in the Haskell Laboratory of Industrial Texicology. He is being addressed in care of the laboratory at Wilmington, Delaware.

Stephen W. Bradford, '39, formerly with the Enterprise Mine at Weaverville, Calif., has returned to his home 545 W. Whiting St., Fullerton, Calif., where he is now being addressed.

W. Horatio Brown, '21, Geologist for the Empire Zinc Division of The New Jersey Zinc Company, who has been located at Gilman, Colorado, for some time, has been transferred to Hanover, New Mexico.

John W. Burns, '36, Engineer for the Consolidated Mining and Smelting Company, has been transferred to Ainsworth, British Columbia.

Alvin L. Cohen, Ex-'43, took his midshipman's oath recently at the United States Naval academy. He placed first on a list of 120 contestants. He was graduated from East Denver High School in 1939 and attended *Mines* before receiving appointment to the Naval academy. He is now being addressed in care of the academy at Annapolis, Md.

J. LeRoy Dana, Ex-'95, Manager, Preparation Division, Incandescent Lamp Dept., General Electric Company, of Nela Park, Cleveland, Ohio, accompanied by his son and daughter-in-law, Mr. and Mrs. Junius Dana, spent a vacation in Denver and Golden recently.

Eugene E. Dawson, '38, is now being addressed at 1456 East Hill Street, Long Beach, California having recently accepted a position with the Brown Drilling Company.

John H. Dismant, '39, is temporarily located at Morenci, Arizona, receiving mail thru Box 966.

Van W. Donohoo, '39, Computor on Seismograph party for the Phillips Petroleum Company is being addressed at present, Box 1369, Beaumont, Texas.

H. A. Dumont, '29, Chemist for the Shell Oil Company, has a change of address from Good Hope to Norco, Louisiana.

Percy Echols, '27, is Chief Metallurgist, Warren Plant, Republic Steel Corporation, and receives mail in care of 98" Mill of the company at Cleveland.

Kirk Forcade, '36, is now being addressed at Navasota, Texas, where he is doing seismograph work for the Phillips Petroleum Company.

Donald I. Gahagan, '27, Geologist for the Skelly Oil Company, has a change of address to 2825 Quenby Avenue, Houston, Texas.

Merle L. Gilbreath, '33, is associated with the McCarthy Drilling Company. His mailing address is P. O. Box 17, Angleton, Texas.

Donald Gunther, '39, is working for the Westinghouse Electric and Manufacturing Company in their Research department at East Pittsburgh. He receives mail at 431 South Avenue, Wilkinsburg, Penna.

Clarence W. Guth, '22, and son, William Allen, spent a vacation in Golden last month with his parents, Mr. and Mrs. Henry Guth. He is connected with the Westinghouse Electric and Manufacturing Company and resides at Irwin, Penn.

Wayne A. Harrod, '16, is Assistant Superintendent, Works Progress Administration, and resides at 821 Green Avenue, Los Angeles, Calif.

James A. Kavenaugh, '38, received appointment recently as engineer in the United States naval aircraft factory at the Philadelphia naval yard. His work will be in the micrographic and spectographic analysis of steel, aluminum and magnesium alloys used in the construction of naval aircraft. Until this appointment he was employed by the Carnegie Illinois Steel company. His address is 7218-D Alderbrook Road, Upper Darby, Penna.

R. E. Knight, '07, formerly Executive Vice-President, is now President of the Alliance National Bank of Alliance, Nebraska, an institution of over fifty years of service.

Milton Lagergren, '33, has moved from Juneau to Fairbanks, Alaska, with address Box 729.

Dent Lay, '35, Sales Manager for the Acetylene Service Company, moved his residence recently to 1543 So. Elizabeth Street, Denver.

Dana W. Leeke, '10, has returned from Korea where he was Mining Engineer for the Oriental Consolidated Mining Company, and is being addressed at his home, 615 No. Fern Avenue, Ontario, Calif.

Morgan Leonard, '36, has completed his contract with Braden Copper Company in Chile and is now at his home, 136 Georgina Street, Santa Monica, Calif.

E. R. Locke, '28, Geophysicist for The Texas Company, was transferred recently to Wharton, Texas.

Russell E. Metzger, '34, in the Personnel department, Manufacturing Plant, New Jersey Zinc Company, resides at 31 Lentz Avenue, Lehighton, Penna.

James S. Miller, '37, has a change of address to Lordsburg, New Mexico, where he is Assayer and Chemist for the Indian Metals Company at their fluorspar mill.

Harold Mitchell, '36, Engineer on Seismograph crew for The Texas Company is now at Bowie, Texas.

James Lester Morris, '33, has resigned his position as Assistant City Engineer of Boise, Idaho, to accept that of Superintendent of the Unity Gold Production Company's mine at Warren, Idaho.

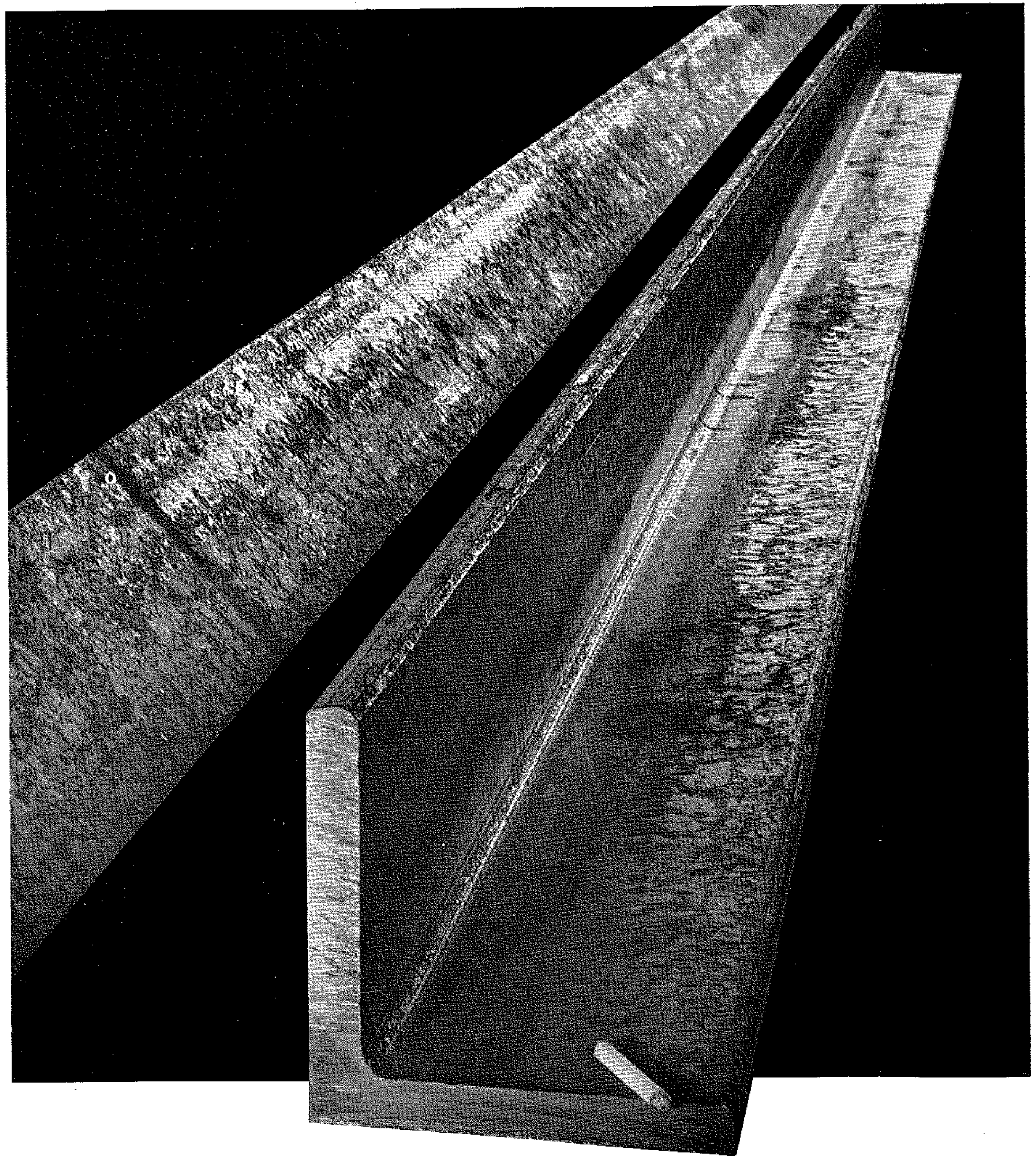
Jim Munro, '39, is employed by the Phillips Petroleum Company as helper on a recording crew. His address is Box 1103, Enid, Okla.

Ben Parker, '24, accompanied by his wife and son, are enroute to the States from Buenos Aires, where he has been engaged in geological work for the Argentine government the past year. He will resume his duties as Assistant Professor of Geology at *Mines* in September.

W. D. Peregrine, '13, has returned from the Philippines where he was Mill Superintendent for the Itogon Mining Company for several years and is at his home in Denver, 190 So. Marion Street.

Clark Schaefer, '38, has succeeded *Robert Barney* as Field Representative for the National Fuse & Power Company. He, with his wife and young son, are residing at 4672 Tennyson Street, Denver.

(Continued on page 463)



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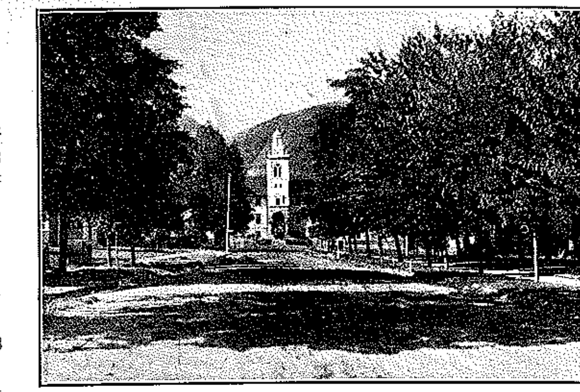

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Tupungato Field, Zona Mendoza, Y. P. F. well. Andes Mountains showing in background. See reference page 397.

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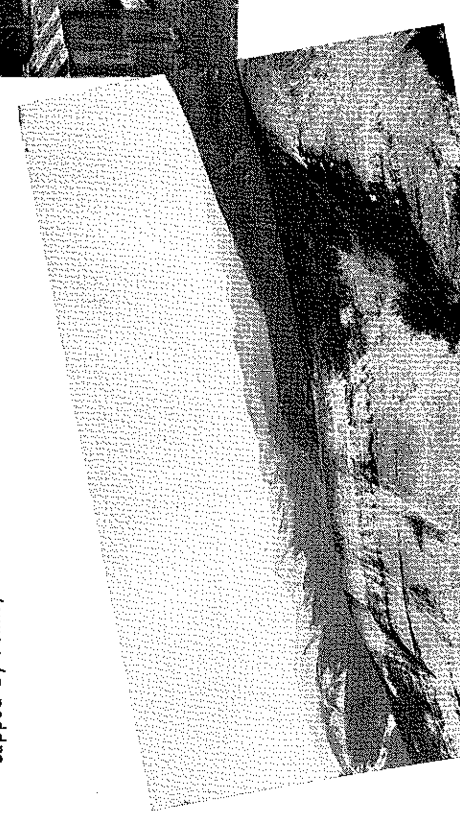
Official Organ of the Colorado School of Mines Alumni Association. Entered as Second Class Matter at the Postoffice at Denver, Colorado, under the Act of Congress of March 3, 1879. Subscription price $3.00 a year. Single copies 50 cents. No additional charge for foreign subscription. Published every month in the year by the Colorado School of Mines Alumni Association. Address all correspondence, including checks, drafts and money orders to Frank J. Nagel, Secretary, 734 Cooper Bldg., Denver, Colo. Address all correspondence relating to Mines Magazine to Frank C. Bowman, Editor, 734 Cooper Building, Denver, Colo.

▼Mountain anticline in Madison (Mississippian) on sky line. Alberta.

▼Crest of anticline in foreground is Madison limestone (Mississippian). Flanks in distance are Cretaceous.

▼Oil well in Devonian on Moose Dome, Alberta. Madison limestone (Mississippian) rises 2,200 feet behind derrick.

▼Moose Dome, Alberta. Banff shale at base, Madison limestone above, both of Mississippian age, form canon wall 2,000 feet high.



▼Looking from crest of anticline across syncline to another anticlinal ridge on sky line. Alberta. Foreground, Mississippian capped by Pennsylvanian. Canon wall 1,800 feet high.

OIL IN WESTERN CANADA

OIL IN WESTERN CANADA

By

JOSEPH S. IRWIN
Consulting Geologist
Calgary, Alberta, Canada

Photo by H. Pollard, Calgary, Alberta.

▼Bad Lands in Belly River Formation (Cretaceous) near Steveville, Alberta.

Whether or not as reader or writer you approve superlatives, you will be forced to deal with them when you read or write about the geology and oil resources of Western Canada.

In Turner Valley oil and gas field, Alberta, occurs the greatest known height of productive oil and gas zone, 5,100 feet from crest of gas cap to oil-water contact plane.

The McMurray (Athabaska) oil sands of Alberta, partly exposed, constitute the largest known oil saturated sand deposit in the world.

Long range in geologic age of producing formations from the somewhat ancient Devonian, more than 200 million years old, to the more youthful Cretaceous, a mere 60 million years of age, more or less, is a record possessed by few oil producing regions.

Types of oil occurrence are exceptionally diverse, ranging from stratigraphic traps of the East Texas and Cut Bank (Montana) type, through the various degrees of simple folds to the unique combination of folding and thrust faulting exhibited in the Turner Valley field.

Although among oil producing regions of the world, Western Canada has not yet attained high rank, the great size of the area over which the petroliferous formations and the few producing localities occur, some 350,000 square miles, together with the limited extent to which it has been explored and exploited, mark it as an oil hunting range offering excellent sport with good chances for success.

LARGE AREA

Western Canada, as here defined from the standpoint of oil and gas possibilities, comprises the Provinces of Alberta, Saskatchewan, and portions of Manitoba and the Northwest Territories. Here we have a triangular area of oil bearing formations, 600 miles wide at base, stretching from the Rocky Mountains to the lake country of Manitoba, and 1,200 miles in length extending northwestward from Montana and North Dakota to a vertex near the Arctic Circle.

Practically lost are the dozen or so oil and gas fields in this domain of some 350,000 square miles. Were these fields the final result of thorough prospecting, little optimism could be felt for the future, but in view of the fact that surface investigation is far from complete and application of geophysics barely started, the combination of great area and wide distribution of productivity suggests good possibilities.

LONG GEOLOGIC AGE RANGE

The great range of geologic age of oil and gas producing formations in Western Canada is perhaps the most unique feature of the technology. This is not only of academic interest but has utilitarian potentialities. Thus, in age range of oil producing horizons, Western Canada is a composite of Montana, Wyoming, Colorado, Illinois, Michigan, Ontario and parts of Kansas, Oklahoma, Texas, New Mexico, Pennsylvania, New York, and West Virginia.

The age and approximate correlation of the more important producing horizons will be briefly listed, starting with the youngest.

Upper Cretaceous

The Bow Island, Medicine Hat, Viking, and Kinsella gas fields (Alberta) produce from sands of Upper Cretaceous age, which sands also yield oil and gas in Montana, Wyoming and Colorado. The recently discovered upper gas in the Steveville (Alberta) field is in the basal Upper Cretaceous sand approximately equivalent in age to the oil bearing Dakota sand of Wyoming, Colorado, and Northwestern New Mexico, and to the Woodbine sand which is the oil reservoir in the East Texas field.

Lower Cretaceous

The oil and gas in the Lloydminster-Vermilion-Wainwright area (Alberta-Saskatchewan), the minor oil production in the Home and Dalhousie sands of Turner Valley field (Alberta), the oil in the Red Coulee field (Alberta), and the enormous partly exposed McMurray (Alberta) oil sand deposits are of Lower Cretaceous age. They are approximately equivalent to the Sunburst and Cut Bank oil sands of Montana.

Jurassic

Strata of Jurassic age, represented by the Fernie shale, are thin or absent over most of the region and are not productive.

Triassic, Permian, Pennsylvanian

Strata of Triassic and Permian age are absent in the area of oil possibilities. Pennsylvanian strata are absent over all except the extreme western foothills where they are thin and as yet unproductive.

Mississippian

The Madison (Rundle) limestone of Mississippian age is the principal source of oil in the Turner Valley field (Alberta) and contains oil in the potential Del Bonita, Spring Coulee, and Twin River fields (Alberta). Limestone of Mississippian age is the main source of oil in the Kevin-Sunburst and Pondera fields of Montana and of the Illinois fields.

Devonian

Formations of Devonian age have not yet become prolific sources of oil in Western Canada, but give promise of favorable results when the widespread nature of oil occurrence in them, and the lack of extensive and thorough testing is considered. Oil in paying quantity at Norman near the Arctic Circle, and oil and gas in significant quantity at Moose Dome, Clearwater and recently at Steveville (Alberta) occur in strata of Devonian age.

The principal oil producing formations of Michigan, western Pennsylvania, southwestern New York, and Ontario, and the recent deeper oil discoveries in Illinois, are of Devonian age. The Hunton limestone oils of Oklahoma and Kansas are of Siluro-Devonian age.

Silurian, Ordovician, Cambrian

The Devonian rocks of Western Canada lie generally on unproductive Cambrian or Pre-Cambrian rocks, the Silurian and Ordovician systems being absent. It is possible, however, that a portion of the strata formerly interpreted as lower Devonian or upper Cambrian may, in some areas, prove to be Ordovician, as is suggested by drilling at Clearwater and Steveville, Alberta.

To summarize the unique and generally favorable situation in Western Canada for testing formations of extraordinary age range:—All possible oil and gas producing horizons of the Cretaceous, Jurassic, Mississippian and Devonian rocks can be tested on the southern plains of Alberta at a depth of not more than 6,000 feet. Northward the depth materially decreases.

Westward toward the geosyncline, which lies immediately in front of the foothills and mountain belt, the depth necessary to test the Cretaceous to Devonian section increases to 13,000 feet, more or less. In the foothills and mountains extreme variations in depths naturally exist, due to the commensurate structural elevation and depression and great topographic relief. In some structures, such as Moose Dome and Clearwater, the entire Devonian section can be penetrated at depths of 3,000 to 3,500 feet.

TYPES OF OIL TRAPS

Diversity of geologic conditions, both structural and stratigraphic, which control or modify oil accumulation in Western Canada, is noteworthy. All important types except salt domes are known. On the plains low dip structures of three degrees to less than one degree occur. In the foothills broad, gentle to narrow folds, and homoclines with inclinations of 20 degrees to vertical, both underlain and overridden by thrust faults, abound.

Turner Valley (Alberta)

Turner Valley structure is an upward and eastward thrust mass of earth crust in which the producing Madison (Mississippian) limestone, buried at depths from 3,700 to 8,500 feet, and closed by combination of folding and faulting against escape of oil and gas, exhibits a productive closure of 5,100 feet in height and as yet undetermined area, greater than 25,000 acres. The height of productive structure is far greater than any other known in the world.

Turner Valley is Canada's only major oil field. One hundred and eleven oil wells in the crude oil area (some 15,000 acres proven and prospective) have potential daily production on one-inch choke of approximately 100,000 barrels. Present (July, 1940) aggregate daily allowable production is 26,000 barrels, restricted to present market demand. Average potential per well is 900 barrels per day. Average allowable per well is 234 barrels daily. Average gravity of oil is 43 degrees A. P. I. Field price of this gravity is $1.20 per barrel. Remaining recoverable oil reserves are variously estimated at 100 million to 150 million barrels. Thirty million barrels of crude oil, condensate, and natural gasoline have been produced to May 31, 1940.

Moose Dome (Alberta)

Moose Dome is a broad, mountain fold of the Salt Creek, Wyoming, type, although unlike the Salt Creek structure it is overridden and underlain by thrust faults on its flanks. The height of the arch is several thousand feet. The flanks are inclined at angles up to 35 degrees. Erosion having laid the central crestal portion of Moose Dome bare down to the resistant Madison limestone core, this domed core forms mountain plateaus and pinnacles which reach an elevation of 7,800 feet. Development thus far has been confined to the canons, 1,500 to 2,000 feet deep, where erosion has proceeded to within a few feet of the Devonian formations.

The perfection of exposure at Moose Dome discloses to the eye what in most other areas must be worked out by laborious and expensive geophysical surveys.

Lloydminster-Vermilion-Wainwright (Alberta-Saskatchewan)

In the Lloydminster-Vermilion-Wainwright district oil and gas occurrence is apparently due to a combination of broad regional structure, local minor structure, and variability of reservoir sands (stratigraphic traps). More information is necessary to reach a conclusion as to the relative importance of the three production-controlling features. East Texas, the world's largest oil field in both production and area, and Cut Bank, second largest in area, both of the stratigraphic trap type, may both be surpassed in area by the Lloydminster-Vermilion-Wainwright district when fully developed.

The shallow depth of producing sands in this district, 1,800 feet average, which is less than two-thirds of the Cut Bank depth and one-half the East Texas depth, operates to offset to some extent the low gravity of the oil, 13.5 to 15 degrees.

Capacities of the few wells thus far drilled in the Lloydminster-Vermilion area have not been adequately determined, but the better wells will probably make 50 to 75 barrels per day. The wells do not compare in size to those of East Texas, but may equal or exceed the Cut Bank wells which average 40 to 50 barrels per day for the first month.

McMurray (Athabaska) Oil Sands

The largest known oil sand deposit in the world is the McMurray or Athabaska sand area of east-central Alberta. If Western Canada possessed no other oil deposit, it would still rank as one of the great potential oil sources of the world. Just when and at what rate this great oil resource will become available on a large scale is, however, at present unanswerable as the oil is heavy, viscous, under no pressure, and must be mined rather than recovered by drilled wells. Commercial availability is also affected by distance from the larger markets, but a start has been made in supplying oil products to northern mining operations.

The Athabaska oil sand deposit is herein classified and listed with occurrences of the stratigraphic trap type, although there is no general agreement as to its mode of origin.

Estimates of oil content in the Athabaska sands can be nothing more than suggestive. Max Ball, who has taken a leading part in the study and exploitation of the Athabaska sands, conservatively suggests a probable area of 20,000 square miles and an acre content of 13,000 barrels, which would result in a total content of 260 million barrels. He warns, however, that probably only one million barrels or so are accessible at present day prices.

Ball is speaking of recovery by mining methods wherein of course the oil content of the mined material is practically all recovered, but the crux of the problem is the amount of material that can be profitably mined. Since, however, the Athabaska oil sands of the McMurray district are presum-

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IMPORTANCE OF RESEARCH IN PETROLEUM GEOLOGY

By
F. M. VAN TUYL
Professor of Geology
Colorado School of Mines

Introduction

The petroleum industry had its beginning when Colonel Drake brought in his discovery well near Titusville, Pennsylvania, in 1859. Since that time, the energies of scientists and engineers working in this field have been devoted almost entirely to the improvement of the art of prospecting and of methods of production and beneficiation. In spite of the fact that there are many fundamental problems relating to the origin and accumulation of oil and gas and the structural and stratigraphic conditions under which they occur, only sporadic attempts have been made to attack these subjects on a systematic basis. The result is that we find ourselves groping in a maze of theories so conflicting in character that the teaching of petroleum geology on the basis of broad underlying principles is well nigh impossible.

It is surprising that this condition has been allowed to persist so long when it should be realized that oil and gas cannot be located in a truly scientific manner until we learn more about their mode of origin and the methods and conditions under which they concentrate into commercial pools. To illustrate this point, we may refer to the theory which was widely accepted a few years ago that prospecting for oil and gas should be confined to areas underlain by marine deposits. We now have convincing evidence that oil and gas may be generated in terrestrial, lacustrine, and brackish-water deposits as well as in marine strata.

Within the past few years, the Research Committee of the American Association of Petroleum Geologists has assumed a more aggressive attitude in an effort to focus the attention of the membership of this far flung organization on the backward state of research in this field. At the present time, the committee under the chairmanship of A. I. Levorsen, is laying the foundation for a concentrated drive on many fronts in an effort to assemble not only field evidence bearing directly on the many problems involved but also experimental data which may be useful in the interpretation of certain phenomena.

Considering the large number of geologists devoting their time to the petroleum industry, it is surprising that research has lagged. It is believed that the attitude of many oil company officials is responsible in large part for the lack of important progress in fundamental studies in petroleum geology. As a rule, such officials have little patience with investigations involving theoretical subjects but are interested primarily in the discovery and the development of new oil fields.

While no assurances can be given that more exact information regarding the modes of origin and accumulation of petroleum would be of practical value in oil field exploration the burden of proof rests on those who deny the possibility of the application of fundamental principles based upon more concentrated field and experimental studies bearing on the problems of the origin and occurrence of petroleum.

Now that we have built up the largest discovered reserve of oil in the history of the industry, we should not be lulled into a sense of security concerning our future petroleum supply. The amount of oil left underground is definitely limited, though certainly not so limited as believed a few years ago, and the time will probably come within the next fifty years when the discovery rate in this country will fall behind the rate of production in spite of everything science can do to promote the finding of new oil fields. In this connection, the recent statement of a well-known petroleum chemist[1] that since nature is generating oil faster than it is being produced and crude oil and its products are being more efficiently utilized "one can look with assurance as to the future oil supplies for our every need for thousands of years" is believed by the writer to be too optimistic. Unfortunately, most of the oil being generated in nature at the present time is either in such positions beneath the sea or in such other relations that it may not become available to man for millions of years, if ever.

According to Lahee,[2] 2319 dry holes and 270 producers (oil or gas) were drilled as wildcats in the United States in 1939. Of the producers, 217 were drilled on technical advice (geology and/or geophysics) while 43 were located for non-technical reasons and 10 were drilled for reasons unknown. 13 per cent of the holes drilled on technical advice were producers as compared to 6 per cent of those drilled without technical advice.

The cost of drilling the 2319 dry holes in wildcat areas during 1939 is not estimated by Lahee, but it certainly is to be measured in tens of millions of dollars. More than 60 per cent of these were located by geologists or geophysicists. If the proportion of successes could have been increased from 13 to 15 or more per cent, the oil industry would have benefited by many millions of dollars, yet relatively small sums, if any at all, are budgeted for research on fundamental problems of petroleum geology by many of the major oil companies.

The argument is often advanced that geology is not a precise science, and that definite predictions regarding subsurface conditions cannot be made. This is true only in part. Witness the rapid advance of the quantitative phases of the subject during the past twenty years as a result of more exact methods in structural geology, petrography, micropaleontology, and other branches. It is undoubtedly true that more searching studies, involving experimental data, may not only reveal why certain structures are barren but point the way to accumulations of oil and gas not revealed by present methods of exploration.

Considering the large percentage of failures involved in the drilling of wildcat wells, even though they have been located upon the basis of careful geological and/or geophysical surveys, it is surprising that more attention has not been given to the more basic problems involved in the origin and accumulation and later history of oil pools in an effort to reduce the large losses sustained in such operations.

In an effort to bring to the attention of oil men generally the present unsatisfactory condition of that part of petroleum geology which deals with these basic subjects, some suggestions for research are presented below. These are grouped under several headings, although there is considerable overlap between certain topics classified separately. In the program of

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[1] Guslav Egloff, "Progress in Petroleum," Science, Vol. 91, p. 535, June 7, 1940.
[2] F. H. Lahee, "Wildcat Drilling in 1939," Bull. Am. Assoc. Pet. Geol., Vol. 24, No. 6, pp. 953-958, June, 1940.

the Research Committee of the American Association of Petroleum Geologists several of these subjects are now receiving attention. It is not contended that all of them can be solved in the near future. In fact, certain problems of this branch of geology probably never will be fully understood.

Origin of Petroleum and Natural Gas

It is generally assumed by petroleum geologists that the commercial accumulations of oil and gas on our planet are of organic origin, although there is abundant evidence that large quantities of these substances on other planets of our solar system are definitely of inorganic origin.

Accepting the view that most of our important accumulations of hydrocarbons are organic, we still have unanswered questions regarding the relative importance of plants and animals as source materials, the parts of these organisms which contribute to oil and gas, and the time in the history of the source beds when the conversion takes place. Some geologists believe that the source material may be stored in the sediments for a long period of time before heat and pressure due to deep burial or other causes bring about a conversion, while others believe that both liquid and gaseous hydrocarbons or a viscous proto-substance are generated even before sedimentation is complete. The study of modern marine deposits has not solved this problem probably for the reason that samples have not been taken at sufficient depth in organic-bearing deposits to throw adequate light on the situation.

The role of bacteria in the preservation of organic debris and in the conversion of certain constituents thereof to oil and gas deserves further study. Again the question arises as to the nature of petroleum or its mother substance in its early history. Does it exist in the strata as a viscous material of complex molecular structure and high specific gravity which may undergo a natural cracking with time to give rise to successively higher grades of oil? If this is the correct explanation, why do we have substantial variations in the grade of crude oil in reservoirs of the same age under different structures and even in different portions of the same pool?

The query also arises as to the interrelations between the pyrobitumens, including "kerogen" of oil shale, the solid and semi-solid bitumens, and petroleum and natural gas.

The high degree of carbonization of the organic matter in certain shales often closely associated with oil and gas horizons should be investigated further. The nature and origin of the carbonaceous material of black shales in general is little understood. Perhaps a petrographic and bacteriological study of modern black sediments, such as those of the Black Sea, would lend light on this question. The time-worn conception that black shales are the chief source of petroleum and natural gas is apparently open to question as there is considerable evidence that limestones and even sandstones may serve as source beds.

Migration and Accumulation

A survey of the opinions regarding migration and accumulation of oil reveals the fact that we can draw no general conclusions regarding either the time, the conditions, or the mode of migration and accumulation. At present, we are handicapped in our efforts to solve some of the fundamental problems involving the time of migration and accumulation by the lack of definite data regarding the constitution of petroleum in its early history. Obviously, we cannot assume important movement of oil through porous strata while and if it is in a highly viscous condition. As additional information is assembled on this important point, a more secure foundation will be laid for research on the concentration of oil and gas.

A few petroleum geologists contend that it is not necessary to assume important movements of oil and gas in the strata in order to obtain commercial pools. They maintain that oil may be generated in considerable quantities within the reservoir itself or in strata immediately adjacent thereto from organic matter present in larger than usual amounts. In certain oil fields the oil is so concentrated in restricted areas that it is impossible to conceive that all of it was generated in situ. Assuming that in many cases there is important movement of oil and gas through rocks, the following pertinent questions may be asked:

1. What is the effect of the various types of sediments, wet and dry, upon the constitution of the oil which moves through them? And what is the influence of certain impurities in the strata?

2. Does accumulation always proceed simultaneously with the generation of oil and gas, or may they exist in a disseminated condition for a long period until changes in the regional geology introduce factors favorable to concentration?

3. Is the final concentration of petroleum accomplished through the movement of small globules of oil, or bubbles of gas enveloped with films of oil, through the strata, or may it move en masse?

4. What is the relative importance of surface tension, differences in specific gravity of water, oil, and gas, compaction of sediments and artesian circulation as factors in concentration under controlled conditions involving different grades of crude oil, variations in amount and kind of associated gas, variable dips, different types of structures, variable size and types of openings in the reservoir, variable temperatures, variable hydrostatic head, variable composition of the water, etc.

5. What part of the factual information available regarding the nature of the movement of oil and gas into producing wells may be applied to the problems of accumulation in nature?

6. Is it possible that oil once accumulated may later be so completely flushed from the reservoir by moving underground water or other causes that little or no trace of it will remain?

7. What is the significance of the occurrence of small amounts of oil in reservoir rocks, either down-dip or up-dip from commercial accumulations in some areas?

8. What is the explanation of the occurrence of oil in dry sands interstratified with marine strata?

9. What is the relation of connate water to the oil and to the sand grains in sandstone reservoirs containing notable amounts of water along with oil?

10. How may the existence of highly porous water sands interstratified with oil sands be explained, especially when the sands are all discontinuous?

11. What relevant data, if any, might be supplied from the study of selected oil seepages?

12. What is the time of cementation of reservoirs, including deposition of calcite in cavities of limestone, as compared to the time of oil accumulation?

13. May the remains of microorganisms present in certain crude oils, as indicated by the work of Sanders, furnish any clue as to the position of the source beds in the section, or were such micro-fossils derived from associated strata through which the oil moved or even from the reservoir itself?

Many of these problems are capable of solution as a result of concentrated field and laboratory studies conducted under the direction of competent investigators.

Paleogeography and Sedimentation

The great importance of stratigraphic traps today and their probable greater importance in the future as a source of oil and gas is drawing increased attention to the problem of developing scientific methods of locating and tracing discontinuous reservoirs of this type. This involves not only a more careful study of nearshore sedimentation as it is going on

(Continued on page 400)

PETROLEUM INDUSTRY OF ARGENTINA

By

BEN H. PARKER, '24
Assistant Chief Geologist
Yacimientos Petroliferos Fiscales
Buenos Aires, Argentina

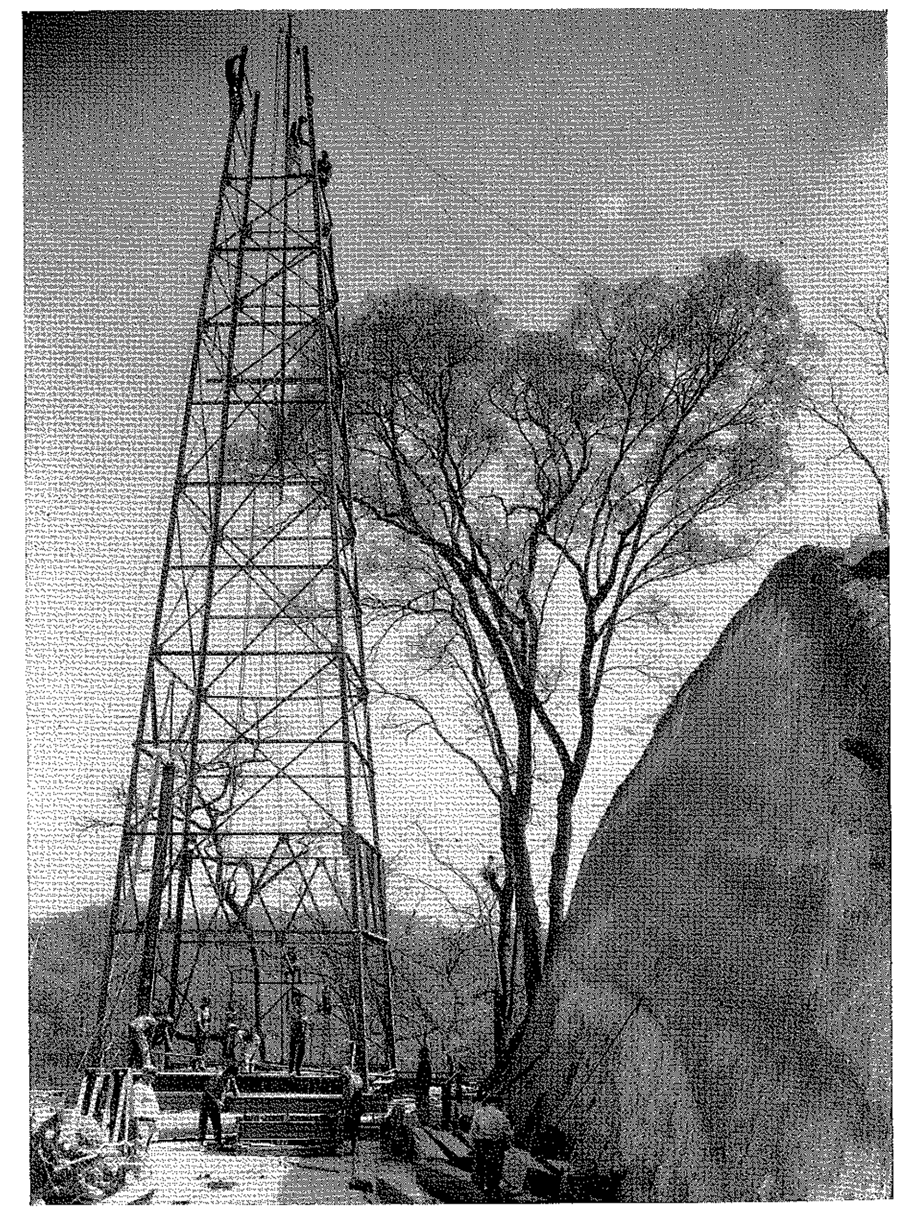
Development of the Industry

The Republic of Argentina occupies an unique position among the important petroleum producing nations of the world inasmuch as the petroleum deposits of the country, although owned and under control of the government, have been developed and exploited both by a government-owned oil company and by private operators. The basic principle underlying the legislation governing the exploitation of the petroleum deposits is that these deposits are the property of the citizens of Argentina and that they should be developed in such manner as to bring the greatest benefit to the citizenship as a whole.

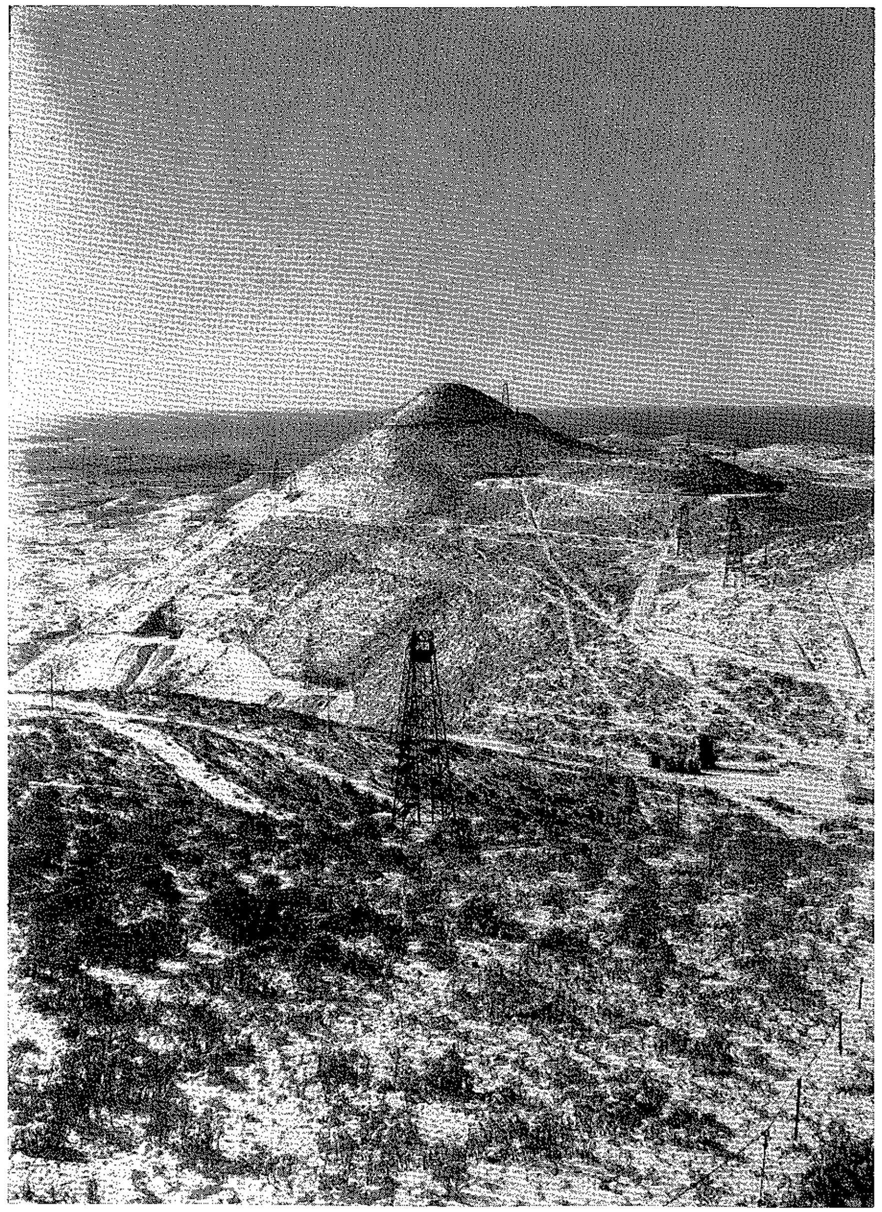
The existence of petroleum and related hydrocarbons in Argentina as evidenced by oil seeps and asphalt deposits has been known since the time of the explorations of the seventeenth century. It was not until the middle and latter parts of the nineteenth century, however, that attempts to discover commercially exploitable accumulations were made. These first prospecting attempts were not successful and further search for commercial deposits was suspended until after the accidental discovery of oil in a well being drilled for water near the town of Comodoro Rivadavia in 1907. This well encountered petroleum at a depth of 537 meters and made an initial production of ten cubic meters per day.

The day following the announcement of this discovery President Figueroa Alcorta signed a decree which prohibited the location of mineral claims by private parties within a radius of five leagues of the center of the town of Comodoro Rivadavia and the first governmental reserve was thus established. Following this initial move toward governmental control and operation of the petroleum reserves the same President, in September 1910, promulgated a law which authorized an extension of the government reserves of 5,000 hectares and opened with the Ministerio de Agricultura a credit of 500,000 pesos for the development of the reserves. Later in the same year the Dirección General de la Exploración del Petróleo de Comodoro Rivadavia was created by presidential decree of President Sáenz Peña.

[1] This article is based in part upon the paper *"La industria del petroleo en la Republica Argentina"* presented by Ing. Mario L. Villa, Gerente General de la Direccion General de Y P F, before the Centro Argentino de Ingenieros. Published by permission of the Direccion General de Y P F.



▼ Fig. 1—Building derrick Y P F well in Tranquitas field, Zona del Norte.



▾ Fig. 3—Producing wells, Y P F Camp No. 3, Zona Neuquen.

By 1916 the governmental production of petroleum from the Comodoro Rivadavia reserves had reached an annual rate of 130,000 cubic meters while in the same year the production of private operators amounted to 7,000 cubic meters. This small production by private operators had resulted from explorations commenced some years before which were based upon the success of the government operations. Notwithstanding this relatively small success of private exploration the entire zones adjacent to the Gulf of San Jorge and to Plaza Huincul, where government operations had made a second commercial discovery in 1916, were covered by applications for prospecting leases. As a direct result of the applications by private operators for prospecting leases embracing such large parts of the known petroliferous areas and the lassitude of these operators in actual exploration drilling President Alvear in 1924 signed a decree ordering an increase in the official investigation of the petroleum deposits and authorizing the revision of the regulations under which prospecting leases were granted.

In 1922 during the presidency of H. Irigoyen the Dirección General de los Yacimientos Petrolíferos Fiscales was authorized and as a result the present organization of the government-owned oil company which is popularly known as Y P F was founded. Since that time, although private enterprises have accounted for an important part of the oil produced in Argentina, the tendency has been toward more widespread control of reserves, production, refining and marketing by Y P F and the history of the Argentine petroleum industry has become to a large degree the history of the government-owned company.

At the present time the entire area of all of the Gobernaciones or territories, with the exception of areas of leases granted prior to the enactment of the present laws, are national reserves subject to prospecting and development by Y P F only. These territories, listed in the following table, together represent an area of 1,209,927 square kilometers or 43.23% of the total area of the country:

	square kilometers
Capital Federal	192
Isla Martín García	2
Islas del Sur	13,133
Formosa	74,500
Chaco	99,600
Misiones	29,800
Los Andes	62,600
La Pampa	143,400
Neuquén	94,100
Río Negro	203,000
Chubut	224,700
Santa Cruz	244,000
Tierra del Fuego	20,900

In addition, by agreement with the provinces of Santa Fe, Córdoba, Salta, San Juan, San Luis, and Mendoza Y P F has secured exclusive prospecting and development rights amounting to 16.09% of the total area of the country.

Provincial reserves totaling an area equivalent to 7.73% of the area of the nation are held by the provinces of Entre Rios and Santa Fe while free zones open for prospecting and development by private operators and Y P F under equal terms and amounting to 32.95% of the area of Argentina exist in the provinces of Jujuy, Salta, Tucuman, Catamarca, La Rioja, Santiago del Estero, Corrientes, Cordoba, and Buenos Aires.

Outline of Argentine Petroleum Geology

In this brief report it is possible to give only a most generalized statement concerning the geology of the various Argentine petroleum deposits. The country with its area of nearly 3,000,000 square kilometers naturally has a wide diversity of geologic features. Rocks ranging in age from Archeozoic to Recent occur under structural conditions varying from the undisturbed attitude of their deposition to structural features of great complexity. Under such widely varying geological conditions it is not surprising that commercial deposits of petroleum have been discovered at widely separated localities and in rocks ranging in age from Devonian to Tertiary.

In extreme northern Argentina production has been found in closely-folded anticlines which trend in a general northerly-southerly direction and which are genetically related to the Andean structure. Productive areas are usually limited to the closed portions of these anticlines where their

normal southerly plunge is interrupted. Surface formations are largely shales and sandstones of Cretaceous and Tertiary age (Fig. 1). The most important production has been found in sandstones of disputed but probable Lower Tertiary and Gondwana age but a recent discovery in rocks of Devonian age opens additional horizons for prospecting.

In Mendoza the largest production has been found in closed anticlines developed in areas of outcrops of Tertiary rocks (See front Cover). The present production here comes from reservoir beds of Rhaetic (Upper Triassic) age. These reservoirs are reached at a depth of approximately 1,800 meters in the Tupungato field, which is the most important field in this region at present, and are of particular interest because of their thickness of some 350 meters and composition of "toba" or volcanic ash deposited in water. The deepest well in Argentina, 2,476 meters in depth, is situated in the Lunlunta field in this district. In the same province production of less commercial importance has been found in Rhaetic beds at shallow depths a short distance from their outcrop on the Cacheuta plunging anticline and in dolomitic limestones of Lower Cretaceous age under closed anticlines situated within a separate basin of sedimentation in southern Mendoza.

In the territory of Neuquen the most important production has been found in sandstones of Upper Jurassic age. Here the structural history of the region has been highly complex and accumulation is controlled both by anticlinal traps and by the overlap of marine shales over the truncated reservoir rocks. In this area three individual oil fields of considerable importance and one gas field have been discovered (Fig. 3). Additional areas thought to have favorable conditions of structure and stratigraphy are now being tested.

The present productive areas in southern Argentina center around the town of Comodoro Rivadavia where the country's first commercial production was discovered. This region is situated within the geologic province termed the San Jorge basin which was an important basin of sedimentation beginning in early Cretaceous time. Production is found in sandstone beds and lenses of Upper Cretaceous age reached at depths ranging from about 550 meters in Campamento Sud to about 1,900 meters in some of the fields more distant from the coast. A considerable number of wells have been drilled in the tidal zone of the coast and in recent years directional wells have bene directed under the sea (Figs. 4 and 5). The pools now developed in this province are on the northern flank of the San Jorge basin where accumulations of commercial importance occur in complexly faulted anticlines which possess a general easterly-westerly trend (Fig. 6).

▾ Fig. 4—Wells in the sea, Zona Comodoro Rivadavia.

Production

In 1938 Argentina occupied the eleventh place among the nations of the world as regards total production of petroleum for the year. In this year Argentina produced a total of 2,714,823 cubic meters out of a total world production of 311,679,244 cubic meters. In 1939 the national production attained a total of 2,959,168 cubic meters of which amount 1,625,204 cubic meters or 54.92% were produced by Y P F while 1,333,964 cubic meters or 45.08% were produced by private operators. (See Fig. 7).

The production at the present time comes from four widely separated geographic zones. These four zones are popularly designated as follows: (1) Zona del Norte, in the extreme northern part of the country in the provinces of Salta and Jujuy; (2) Zona Mendoza, in the Province of Mendoza in the west-central region at the foothills of the Andes Mountains; (3) Zona Neuquén in the west-central part of the country in the territory of the same name, and (4) Zona Comodoro Rivadavia, in the southern part of the republic in the Territory of Chubut. Based upon 1939 production these zones possessed the following relative importance:

	cubic meters
Zona Comodoro Rivadavia	2,351,266
Zona del Norte	271,947
Zona Neuquen	206,526
Zona Mendoza	129,429

The 1939 production obtained by the various operators in the four producing regions was in accordance with the following tabulation:

Zona Comodoro Rivadavia

	cubic meters
Yacimientos Petroliferos Fiscales	1,316,931
Diadema Argentina (Royal Dutch)	668,689
Compania Ferrocarrilera de Petroleo	152,655
Astra S. A.	133,673
Solano	45,013
Compania Industrial y Comercial de Petroleo	34,305
	2,351,266

Zona del Norte

	cubic meters
Standard Oil Company	193,934
Yacimientos Petroliferos Fiscales	78,013
	271,947

Zona Neuquén

	cubic meters
Yacimientos Petroliferos Fiscales	101,862
La Republica, Ltd.	65,877
Standard Oil Company	37,524
Astra S. A.	1,263
	206,526

Zona Mendoza

	cubic meters
Yacimientos Petroliferos Fiscales	128,398
Rio Atuel	1,031
	129,429

Drilling and Recovery

Throughout the producing areas of Argentina both the private operators and Y P F have continually attemped to take full advantage of the rapid technical progress made in drilling and production methods by operators and technologists in other countries. In order to achieve this the new drilling and production equipment developed in other regions has

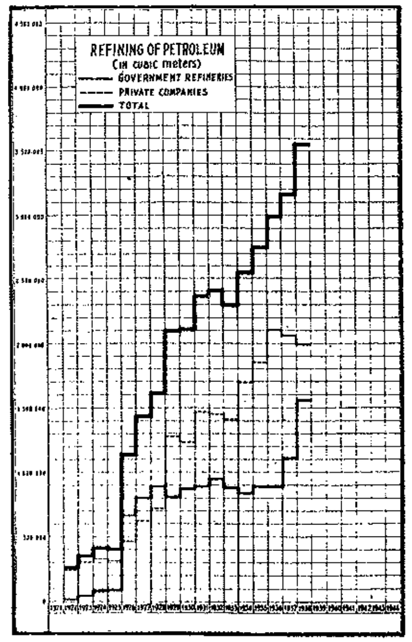
▼ Fig. 5—Y P F Camp Comodoro Rivadavia.

been adopted as rapidly as justified and demanded by local conditions. Foreign operating companies have, quite naturally, depended to a large extent upon technical and engineering personnel trained and experienced in foreign fields. Y P F, on the other hand, has used to a much greater degree native Argentine engineering and technical personnel. In order that this personnel could obtain a knowledge of operating methods in other countries the policy of sending experienced engineers to foreign countries (largely to the United States) for observation of current drilling and production technique has been common. No direct comparison of the drilling and production efficiency of the various Argentine operating companies is available but the progress in drilling made by Y P F is indicated by the average daily drilling advance per equipment. In Zona Comodoro Rivadavia this drilling advance per day has increased from 2.016 meters in 1923 to 17.095 meters in 1938 or an increase of 748% in five years.

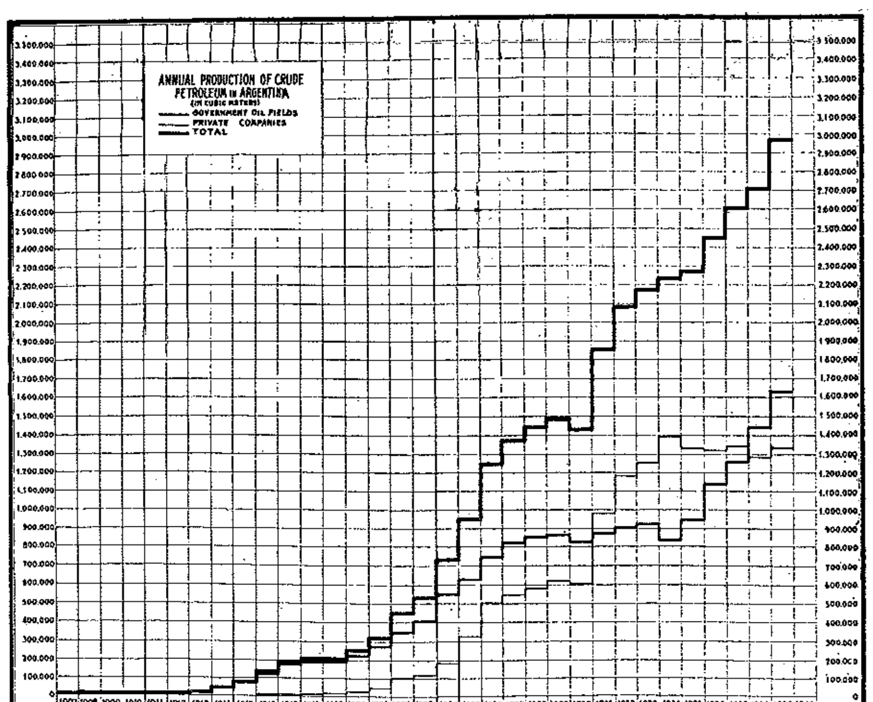
Until the end of 1938 4,511 wells had been drilled in the four producing zones and of these wells 2,995 were still producing oil or gas at the end of that year. Of the 2,995 producing wells 1,993 or 66.54% were owned by Y P F and 1,002 or 33.46% were owned by private operators.

Cable tools, rotary equipment, and combination rigs have been used at various times during the quarter century of Argentine petroleum produciton. At the present time, however, rotary equipment is used practically exclusively with only a small amount of cable drilling equipment retained for special drilling problems. The supply of drilling mud for rotary drilling has been a considerable problem as in most of the country the formations encountered in drilling are not mud-forming and local supplies of good mud-forming shales are not available in many areas. Satisfactory supplies of bentonite and barite occur in some parts of the country, however, and these are widely used in the preparation of drilling mud.

Electric, diesel, and steam power are used for drilling in the various zones the choice depending upon local conditions. Practically all drilling and production equipment, with the exception of special equipment fabricated in the company shops, is imported either from Europe or the United States.



▼ Fig. 8—Chart showing the annual runs of crude petroleum in government-owned and private refineries in Argentina.

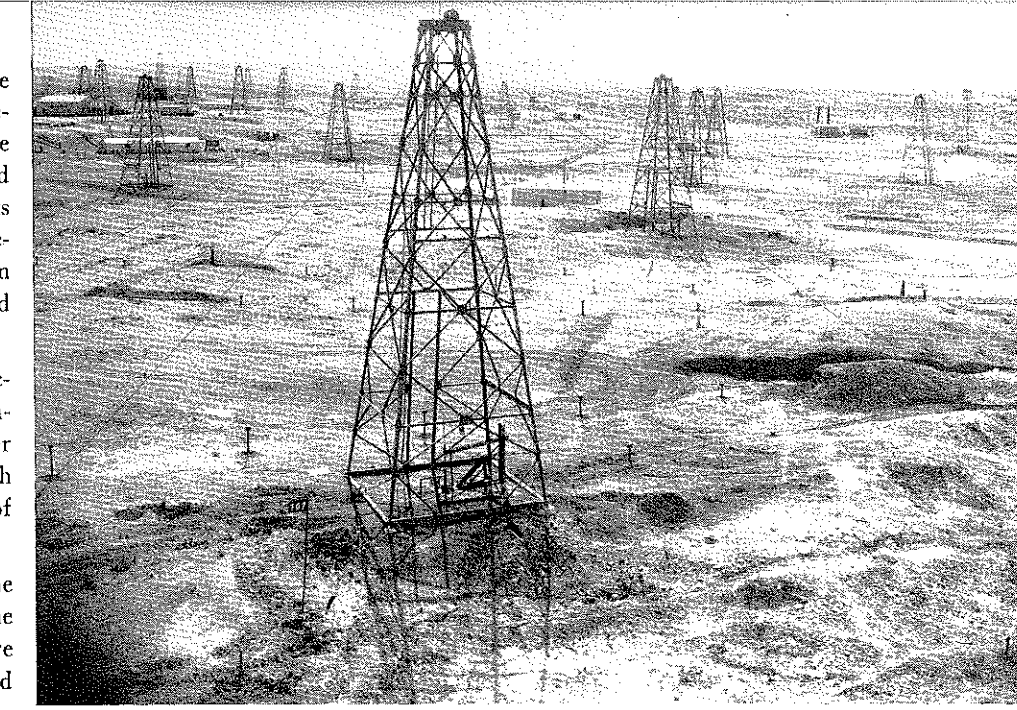


▼ Fig. 7—Chart showing the annual production of crude petroleum in Argentina.

Production technique has been the subject of considerable study but because of the relative large size of the holdings of the various operators and the absence of divided royalty interests the problems of production and recovery are distinctly different from those encountered in the United States.

Repressuring by gas input is accomplished in a few fields where conditions justify this. No artificial water flooding has been attempted although studies of this and other methods of forced recovery have been made.

The following tabulation shows the production methods utilized in the 1,854 wells of Y P F which were rated as producing wells at the end of 1939:



▼ Fig. 6—Y P F wells in Zona Comodoro Rivadavia.

	Zona Comodoro Rivadavia	*Zona Neuquen*	*Zona Norte*	*Zona Mendoza*	*Total*
Mechanical lift	1,539	96	13	23	1,671
Natural flow	23	14	15	12	64
Gas lift	7	48	50		105
Swab	4	2		1	7
Testing	6			1	7
Total	1,579	160	78	37	1,854

In addition to the above listed oil wells, Y P F had 119 productive gas wells at the end of 1939.

The average daily production of the government-owned wells in each of the four productive areas in the year 1939 is shown in the following table:

Zone	*Number of wells*	*Average daily production per well cubic meters*
Comodoro Rivadavia	1,579	2.911
Neuquen	160	2.129
Norte	78	3.567
Mendoza	37	48.592

Storage and Transportation

The total storage capacity for crude petroleum and refined products in Argentina amounts to approximately 1,800,000 cubic meters exclusive of some 1,000,000 cubic meters of storage capacity allied to the electric generating plants of the country. Of this storage capacity Y P F owns about 770,000 cubic meters distributed among its four productive zones, five refineries and 19 bulk storage plants.

At the present rate of national consumption of petroleum products the nation's storage capacity for crude and refined products is equivalent to between one-third and one-half of the annual requirements.

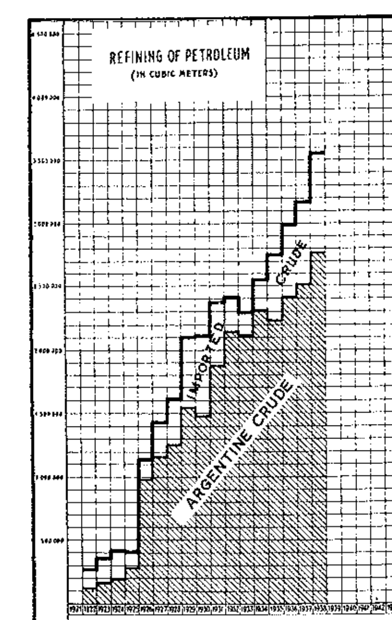
Owing to the widespread distribution of the developed petroleum deposits and their distance from the major centers of population and principal industrial areas the transportation of both the crude and refined products is an important problem of the national industry. Trunk pipe lines have not been constructed and the only existing pipe lines are gathering lines in the various fields and comparatively short lines connecting the fields with terminals for later shipment by sea or rail.

At the present time the greater part of the production from the fields in Neuquén, Mendoza and Zona del Norte is transported by rail to tide water although some of the production from Zona del Norte moves thru pipelines connecting the fields with rail shipping points from which the oil is transported by tank cars to the Río Paraguay where it is shipped by river barges to refining centers.

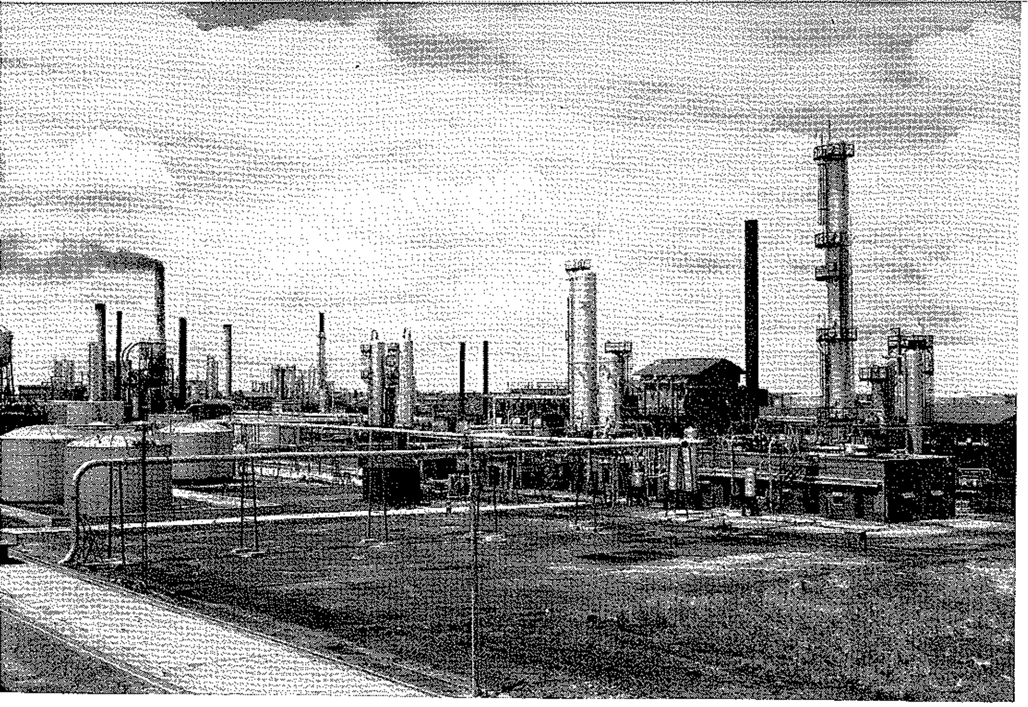
The production from the Comodoro Rivadavia area is transported by gathering lines and short connecting lines to the coast where it is shipped by tankers to the refining centers in the vicinity of Buenos Aires. The major Argentine tankers are 24 in number with a combined net tonnage of 183,000 tons. Thirteen of these units with a net tonnage of 105,000 tons belong to private operators while 11 units aggregating 78,000 net tons are owned by Y P F.

Refining

There are 18 refineries in operation in Argentina and one new plant under construction at the present time. These plants have a combined annual capacity of approximately 4,657,000 cubic meters. Y P F owns and operates five of these refineries with a total capacity approximately equal to that of the combined capacity of the 13 privately owned plants (Fig. 8). The privately owned refineries operate both



▼ Fig. 9—Chart showing the annual runs of nationally produced and imported crude petroleum in Argentina.



▼ Fig. 10—Y P F refinery La Plata.

on crude of national production and imported crude while the Y P F refineries run Argentine produced crude exclusively (Fig. 9).

The refining capacity is in large part of modern design employing late developments in cracking processes (Fig. 10). The plants are designed to produce all of the products which the national market requires. The refining industry employed a total of 3,861 employees in 1938 and represented a reported capital investment of 112,455,779 pesos in the 18 plants.

Marketing

The marketing of petroleum products in Argentina is unique because of the dominating position held by Y P F. That organization as well as the private operating companies maintain extensive wholesale and retail outlets for their products. The large refining and distributing facilities of Y P F enable it to control effectively the price of products to the consumer and since the inception of retail marketing by the government-owned company in 1923 the trend has been for a continual lowering of the price of the products to the consumer. One notable feature effected by this control has been the establishment of a uniform price for gasoline throughout the country and gasoline may be purchased for the same price in the most remote region as in the vicinity of the refining centers.

Consumption and Reserves

Although for some years Argentina has held the eleventh place among the petroleum producing nations of the world it has occupied the seventh place among the consuming nations. In per capita consumption of petroleum products Argentina is surpassed only by the United States and Canada.

The total consumption for the year 1938 as indicated by the national production and imports is shown in the following table:

National production of crude oil		2,714,824 cubic meters 53.9%
Imports		
Fuel oil	1,119,1111	
Crude oil	789,837	
Diesel oil	387,995	
Gas oil	21,474	
Gasoline	2,759	
Miscellaneous oils	94	2,321,270 cubic meters 46.1%
Total of national production plus imports		5,036,094 cubic meters 100.0%

Just as the world reserves of petroleum are difficult of estimate so are the known reserves of Argentina. Conservative calculations of the Argentine reserves made in the years 1934, 1936 and 1939 have each indicated reserves equivalent to 12 years production at the current rates at the time of the surveys. Inasmuch as the annual production rate has increased from some 2,200,000 cubic meters in 1934 to 2,900,000 cubic meters in 1939 it is evident that considerable progress in the expansion of reserves has been made. These estimated national reserves compare quite favorably with the world estimate of an equivalent of 16 years consumption recently made by a committee of the American Petroleum Institute. In connection with these calculated reserves it is interesting to note that although the major part of these reserves are in the area of Comodoro Rivadavia the new and yet but partially developed recent discoveries of greatest importance have been in other areas. This would seem to indicate that prospective areas still undeveloped may in future years augment greatly the developed reserves of the nation.

Research in Petroleum Geology—

(Continued from page 394)

today but also the more exact determination of the position and trend of deposits of the shore zone containing porous sands as well as of truncated porous strata capable of serving as reservoirs of oil and gas in the older strata. There will be not only a careful re-study of oil well cuttings and cores but also considerable exploratory drilling in future years in an effort to map the areas holding the greatest promise for stratigraphic accumulations. All of this involves the development of more refined criteria for the recognition of shallow water deposits and of unconformities than are available at the present time. The influence of the topography of the surface on which sediments are deposited and of incipient dips related to geosynclinal development upon the localization and character of ensuing structures also offers a fertile field for investigation.

The effect of lateral variations in sediments upon differential compaction and upon the quantity and character of source organisms should receive further attention.

Another item worthy of serious consideration is the question of the time and conditions of cementation of sands, both marine and continental. Is the cement of a local source or is it introduced by circulating waters? Is it of more than one generation? Is it deposited in some cases while the strata are still beneath the sea or after they have become a part of the land? Why do certain types of cement vary greatly in amount both in the plane of the strata and at right angles thereto?

Problems of Structure

The lack of appreciation of the importance of careful analytical study of oil field structures is reflected in the classifications of productive structures which have appeared in the literature. No distinction is made between simple folds formed during one period of deformation and those developed through successive rejuvena-

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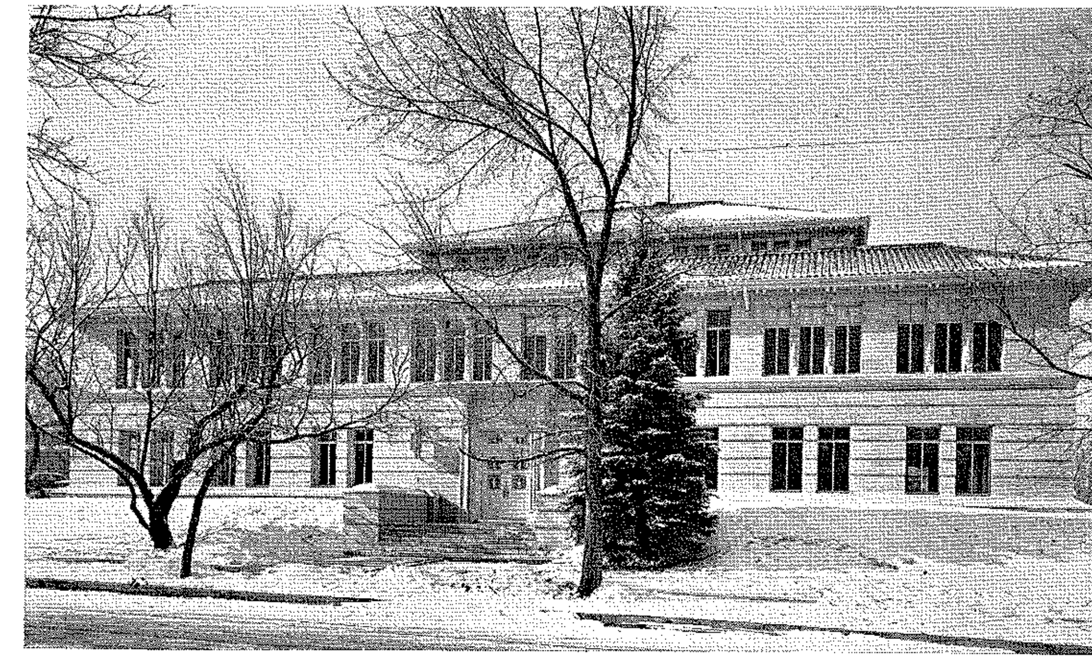


▼ Fig. 1.

View of Geophysics Wing.

EQUIPMENT AND LABORATORIES

Department of Geophysics at "Mines"

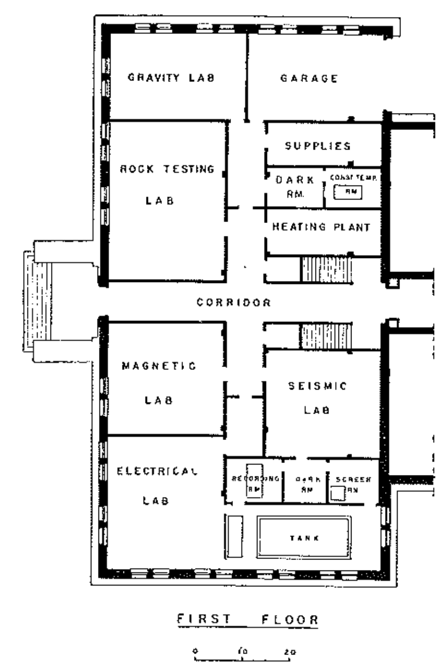
By

C. A. HEILAND
Professor of Geophysics

About a year ago, I had the opportunity of giving the readers of the Mines Magazine a preliminary description of the geophysical laboratories under construction at that time. Since then, the geophysics addition to the Geology Building has been completed, and a substantial amount of new equipment has been acquired. The Department moved into its new quarters in December, 1939. This article will present a description of its new equipment and laboratories largely through the medium of illustrations. These will, perhaps, give a better conception of our facilities for instruction and research than a lengthy discussion.

An exterior of the geophysics addition appears in Fig. 1. The two floor plans are given in Figs. 2 and 3. The first floor contains the majority of the laboratories, a garage, a supply room, and the heating plant. On the second floor are an Electronics and a Well-Testing Laboratory, a Lecture Room, a Graduate Room, a Library, several offices, and a Photostat Room. The overall outside length of the Geophysics Wing is 115 feet, and its width is 62 feet.

The necessity of solid instrument foundation accounts for the location of most laboratories on the ground floor. A pillar to bedrock was provided in the recording room between the seismic and electrical laboratories. Two other foundations were placed on a six-inch layer of cork for vibration damping. One of these is located in a screen room attached to the seismic laboratory and serves as a test block for seismic detectors. The other, situated near the model tank in the Electrical laboratory, supports D. C. and A. C. generators of various frequencies, employed in model tank experiments. For torsion balance and magnetometer work, no special foundations were



▼ Fig. 2. First Floor Plan.

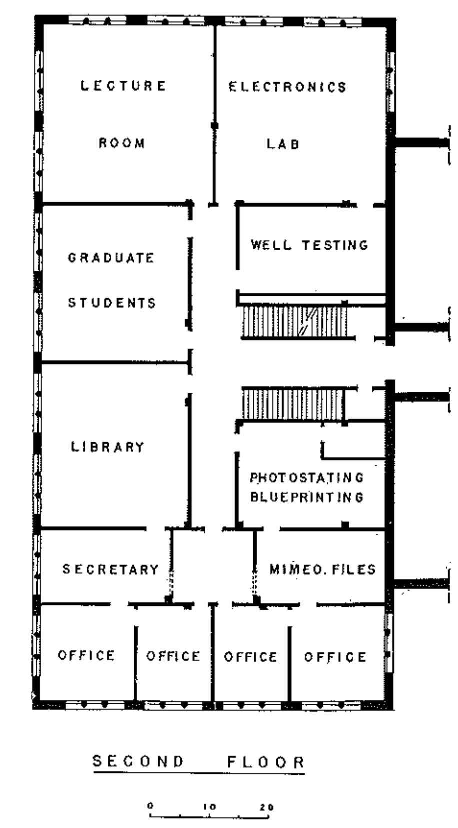
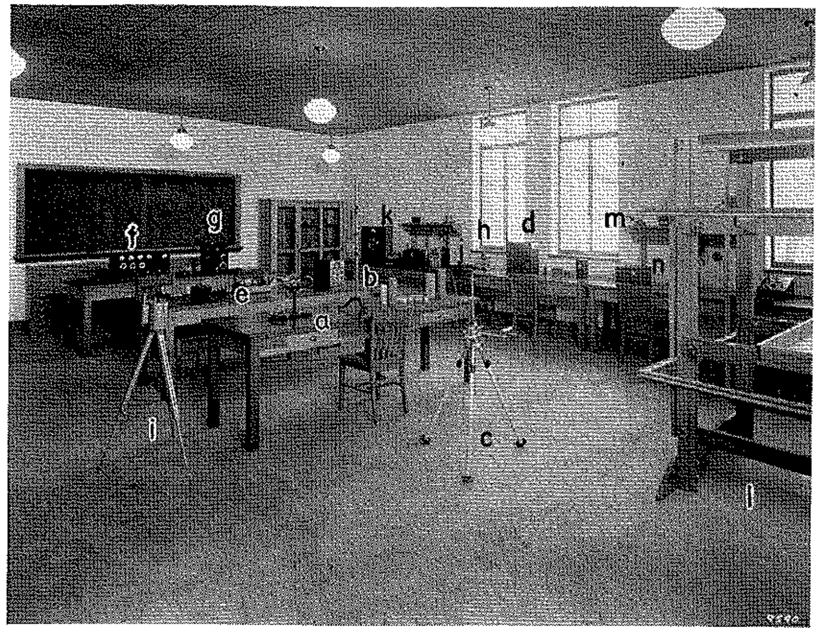
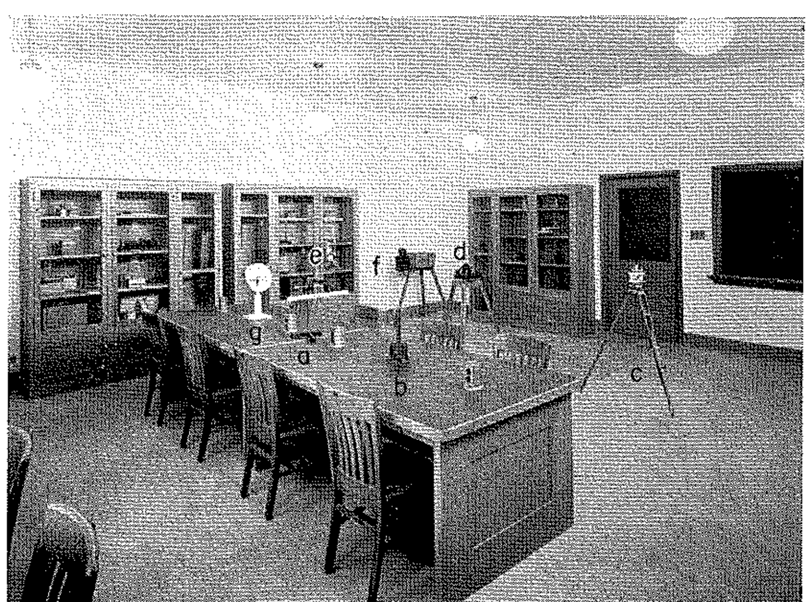


Fig. 3. Second Floor Plan.





provided since the concrete slab on the first floor lies directly on solid ground.

One large laboratory was set aside for the purpose of testing physical properties of rock specimens and drill cores. A knowledge of these properties is important not only in the interpretation of geophysical data but also in determining the applicability of geophysical methods to given geologic conditions. In the Rock Testing Laboratory a number of apparatuses are set up permanently or semi-permanently to make possible a rapid measurement of rock properties. In Fig. 4, *a* is a beam balance and *b* a Jolly balance for the determination of densities; *c* is a unifilar magnetometer, and *d* is an inductance bridge for measuring magnetic susceptibilities. An astatic magnetometer is now available for the same purpose though not illustrated. Resistivities of drill cores are determined with the setup *e;* the bridges *f* and *g* are intended for measurements at high frequencies and radio-frequencies. Radioactivity is observed with the electroscope *h,* the Ambronn emanometer *i,* or the Geiger counter (*j*). Elastic properties of rock specimens are measured with the arrangement *k,* consisting of a beat frequency oscillator, a clamp holding the specimen, and a sound level indicator to record the vibration amplitude. Equipment for hydrocarbon analysis is located on the other side of this room and is not shown in the figure. Under the blackboard, in the rear of the Rock Testing Laboratory, may be seen a number of storage cabinets in which typical rock specimens of representative properties are kept for further use in instruction and research. A diamond saw is available to cut rock specimens to predetermined dimensions.

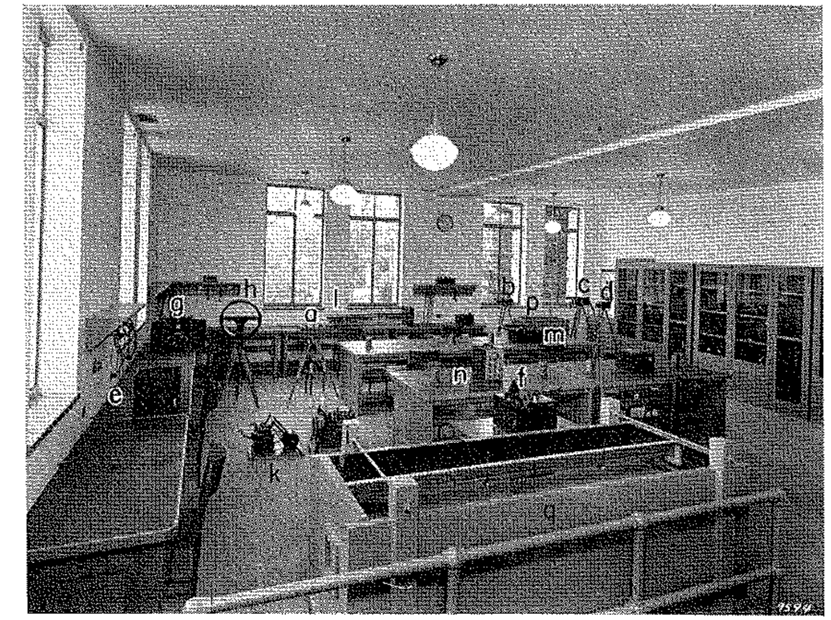
In Fig. 4, *l* is a setup for magnetic model experiments which was placed in the Rock Testing Laboratory for lack of space elsewhere. This setup consists of a pair of Helmholtz coils to produce any desired values of the earth magnetic horizontal and vertical components, thus simulating magnetic latitude. The magnetic model is placed in a tray. The earth's surface is represented by a platform on which is placed a miniature inductor *m* connected to an amplifier *n* and a galvanometer. The earth inductor can be arranged in any desired position with reference to the model (magnetized by A. C.). Both vertical and horizontal anomalies may be measured by adjusting the plane of the inductor in horizontal or vertical planes.

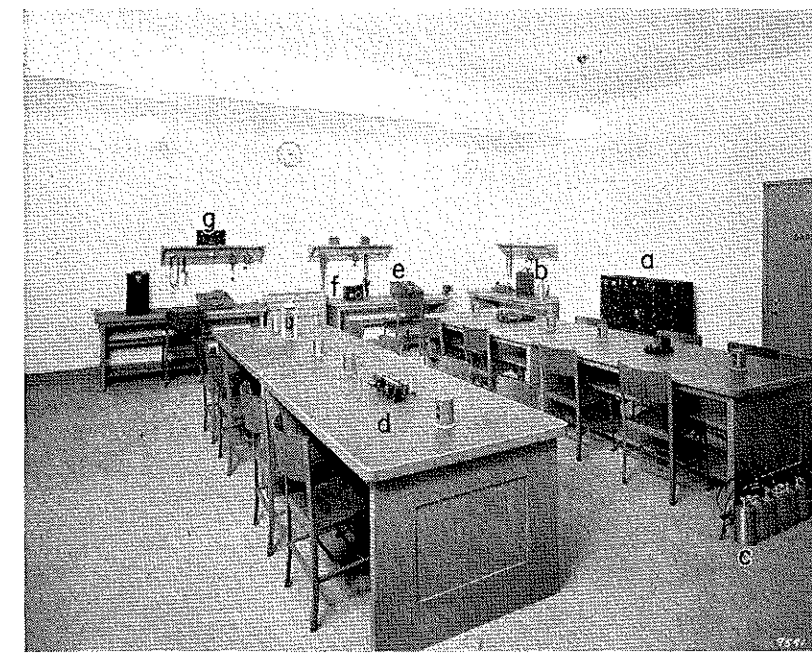
▾Top—Fig. 4. Rock Testing Laboratory.
▾Center—Fig. 5. Gravity Laboratory.
▾Bottom—Fig. 6. Magnetic Laboratory.

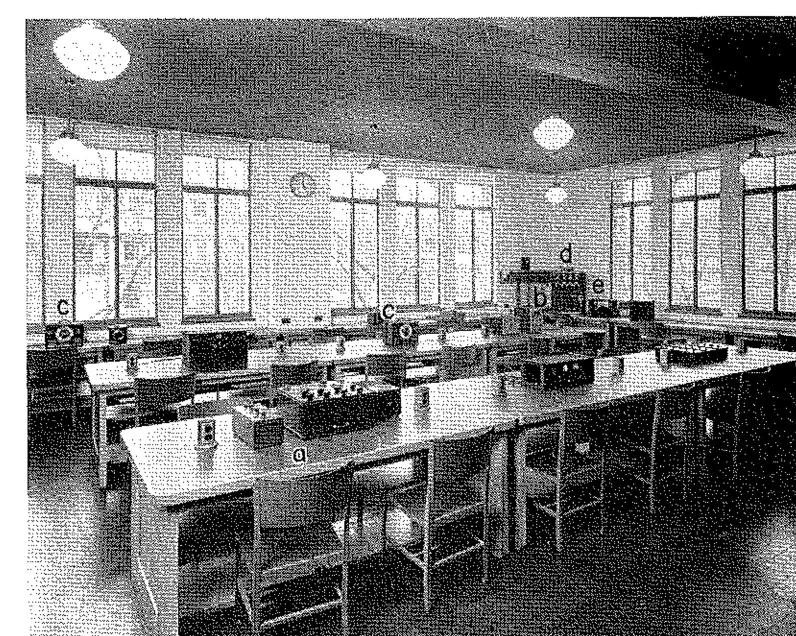
The Gravity Laboratory (Fig. 5) is intended for work on torsion balances and gravimeters. *a* shows students preparing a torsion wire; *b* is a setup for the treatment and calibration of wires, and *c* a Z-beam torsion balance. Associated with this laboratory is a dark room, and a constant temperature room (see Fig. 2) for determining temperature coefficients of gravimeters and other instruments. For field work with the gravimeter a compartment is provided in the rear of the seismic recording truck (Fig. 14).

In the magnetic laboratory (Fig. 6) the fundamentals of magnetic deflection and oscillation measurements may be demonstrated with the instruments *a* and *b*. Two vertical (*c*) and one horizontal magnetometer are available, as is an earth-inductor *d* with loop-galvanometer *e,* a variation recorder *f,* and equipment for determining scale values and temperature coefficients of magnetometers. *g* is a model demonstrating the action of the earth's magnetic field on a freely moving magnetic needle.

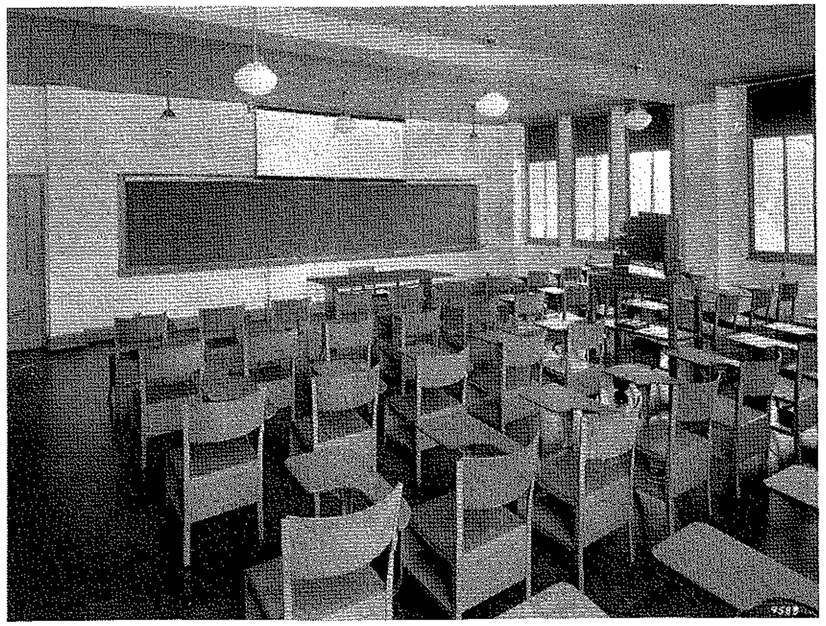
The Electrical laboratory, illustrated in Fig. 7, contains equipment for work with the self-potential method (*a*), resistivity apparatus (*b* = potentiometer, *c* = commutator, *d* = milliammeter), the potential drop ratio equipment (*e* and *f*) and the electromagnetic equipment (*g* and *h*). Portable generators are available for 25 cycles, 60 cycles (*i*), 500 cycles and 900 cycles (*k*). *l* is a Metallascope for the detection of metallic objects at shallow depth; *m* and *n* are oscillographs. Three tanks are available for model experiments. The smallest of these (*p*) is used mostly for resistivity interpretation; the next size (*q*) is shown as arranged for potential-drop-ratio measurements. The largest tank, indicated in the lower right hand corner of Fig. 2, is made of cement, is 19 feet long, 8 feet wide, and 7 feet deep. It is intended for model work with potential and inductive-electromagnetic methods. A traveling crane (made entirely of wood to avoid stray fields) may be moved into any desired position with respect to the model bodies below. It carries a rotatable beam on which may be placed the contact electrodes for potential work, or a search coil for experiments with inductive methods. Equipotential-line and potential-profile experiments are made with a weakly electrolytic solution in the tank. When working with inductive methods, the tank is used in empty condi-

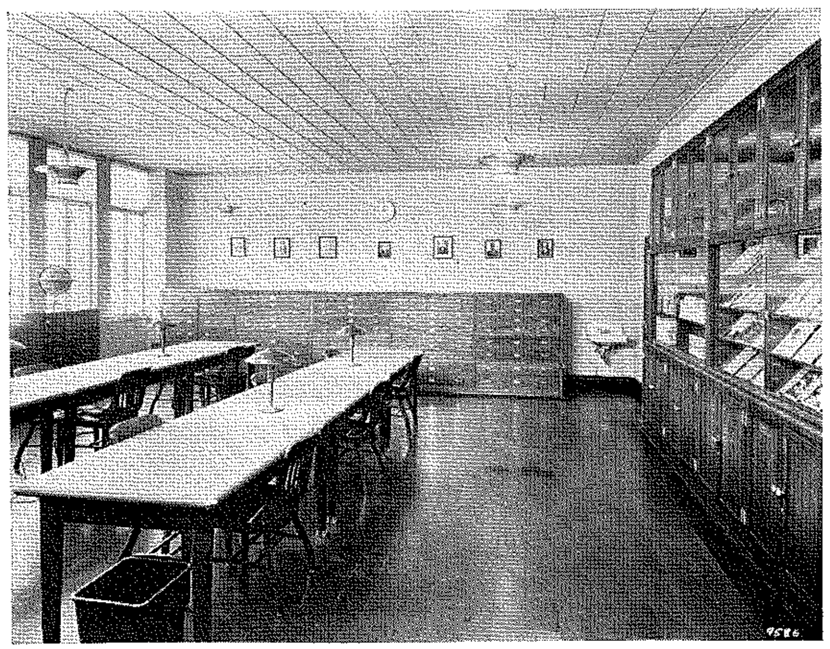


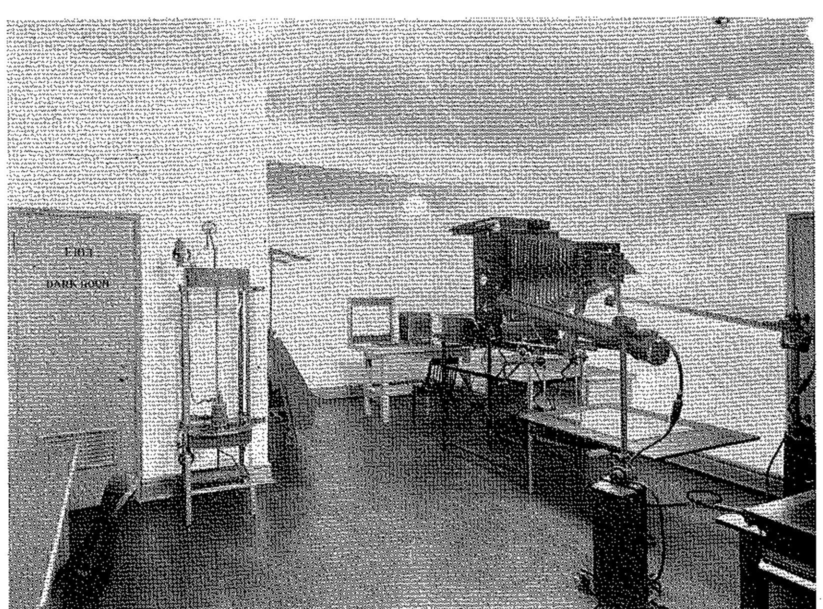




▾Top—Fig. 7. Electrical Prospecting Laboratory.
▾Center—Fig. 8. Seismic Laboratory.
▾Bottom—Fig. 9. Electronics Laboratory.







tion and the models are energized by a rectangular loop permanently installed around the tank and supplied with current of a frequency in keeping with dimensional model relations.

The Seismic Laboratory shown in Fig. 8 is intended primarily for the testing of seismic equipment. The 6-channel reflection seismograph *a* setup on the wall of the laboratory is ordinarily installed in the seismic recording truck shown in Fig. 14. A part of this equipment are the blaster *b* and the detectors *c*. A standard 100 cycle fork *d* is used for checking timers. Accessory testing apparatus are: an impedance bridge *e*, a microvolter *f*, constant impedance divider *g*, and various other bridges, meters, and recording instruments not shown. Two pairs of acoustic geophones and two mechanical 2-component seismographs are available for demonstrations.

Associated with the seismic laboratory is a dark room, a recording room and a screen room. The recording room has a seismograph pillar extending to bedrock. The screen room is intended primarily for seismic test block experiments. The shaking table is driven from a beat-frequency oscillator through a power amplifier and the table amplitude is recorded with a standard pickup connected to an oscillograph-galvanometer. To make possible the use of high-gain seismic amplifiers, both the recording room and the screen room are surrounded by double Faraday copper screen cages which shield them from electrostatic and electromagnetic fields. The screen rooms are purposely located between the seismic and electrical laboratories for the convenience of testing electrical prospecting instruments requiring freedom from extraneous interference.

A garage has been provided on the south side of the ground floor for the seismic and gravimeter truck and the torsion balance hut and trailer. The seismic shot hole drill is stored elsewhere. A small amount of shop equipment, such as a bench lathe, a drill press, a power saw and a grinder is likewise located in this garage.

The supply room contains a stock of meters, transformers, condensers, resistors, tubes, light bulbs, chemicals, and other accessories required for instruction and research.

Two other laboratories are located on the second floor. One is the Electronics Laboratory (Fig. 9) intended for instruction in the elements of communication engineering and geophysical applications of electronic devices. Available equipment includes universal bridges (*a*) with standard condensers, inductances, resistances; cathode ray oscillographs (*b*), oscillators (*c*), radio transceivers, vacuum tube voltmeters, etc. In the rear of the room is a short-wave radio transmitter (*d*) and an all-wave receiver (*e*). The transmitter is connected to an antenna extending from the top of Berthoud Hall to Guggenheim Hall (see Fig. 1). The Well Testing Laboratory is used at present as an overflow room for Electronics equipment and instruction but will serve later for demonstration and research in connection with the measurement of temperatures, resistivities, spontaneous potentials, and radioactivities in wells.

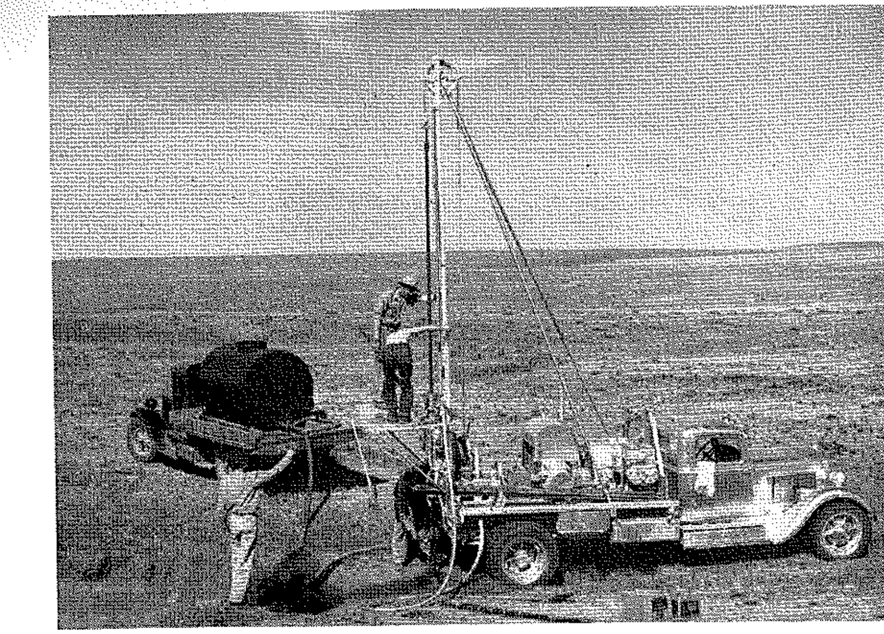
▾Top—Fig. 10. Lecture Room.
▾Center—Fig. 11. Library.
▾Bottom—Fig. 12. Blueprint and Photostat Room.

Fig. 10 shows the lecture room for geophysics. It accommodates 50-60 students, is acoustically conditioned and is equipped with a projector for lantern slides and opaque objects. Next to it is a room for graduate students, each of them having an individual desk and book space. A drafting table with universal drafting set, a shadowless tracing table, and calculating machine are provided for the student's convenience.

Fig. 11 shows the departmental library and reading room. The bookcase on the right contains periodicals, magazines, catalogs, reprints, and other printed material related to geophysics, oil, mining, engineering, geology, and physics. The cabinet in the rear of the library room contains geological and geophysical survey maps, circuit diagrams, interpretation graphs, seismic records, and lantern slides. On the north side of the second floor are four offices for instructors and a stenographer's office. One room contains files of lecture and laboratory notes, calculation forms and other mimeographed material, with an available space of 60 file drawers.

Reproduction of geophysical surveys and geologic data, and the duplication of diagrams and maps of all kinds are procedures unavoidably associated with geophysical exploration. The acquisition of the equipment shown in Fig. 12 is expected to result in an appreciable reduction of the department's expenses for work of this kind. The equipment includes (from left to right in Fig. 12): a blueprinting machine, a wash-rack for blueprints, a reproduction camera for making lantern slides, and a photostat machine (Rectigraph) with associated Cooper-Hewitt lighting equipment. These reproduction facilities are also available to other departments in the school.

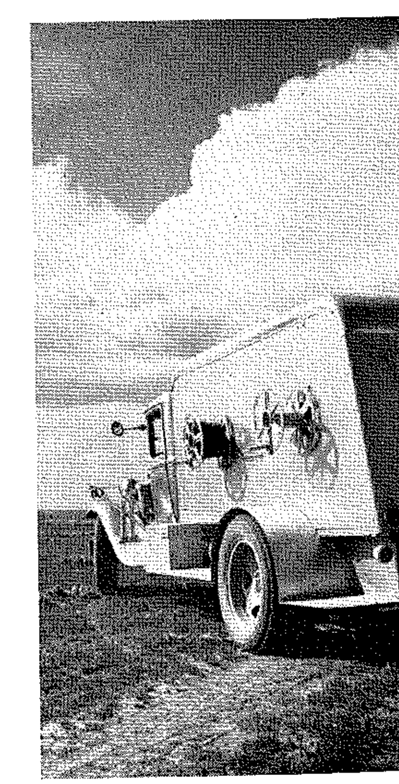
A description of the department facilities would not be complete without mentioning briefly some of the



▾Fig. 13. Shothole Drill in operation. Water truck in background.

field equipment now available. This equipment is intended mainly for reflection seismograph and gravimeter surveys. For other geophysical methods, such as magnetic and electric, little field equipment is required beyond the instruments previously mentioned in connection with the respective laboratories. A truck-mounted rotary shot hole drill, originally constructed by Longyear and remodeled by the department, is used in the seismic field work. The main improvements on this drill have been the installation of an auxiliary power engine and of dual rear wheels. The body of the seismic recording truck has been completely rebuilt for the new six-channel reflection equipment and provision has been made to add amplifiers and galvanometers for six more channels. In the rear of the seismic truck is a gravimeter compartment with an arrangement to lower the instrument to the ground through the floor. The Department usually rents a water truck for the seismic work; there is no separate shooting truck. Fig. 13 shows the drill truck and the water truck on location. Fig. 14 is a view of the seismic recording truck. The field work in the spring includes, besides the seismic survey, a complete topographic, magnetic and gravity survey of an area about 100 miles east of Denver. Geophysical work on mining problems involves the application of magnetic, self-potential, resistivity, equipotential-line and magnetic methods on a pyrrhotite ore body a few miles from Golden. This work is generally done on weekends during the first semester.

The new laboratory and equipment facilities which have been briefly described above make the Geophysics Department of the Colorado School of Mines the largest and best equipped of any educational institution in the world. The perfection of the present organization has required tireless work on the part of all members of the Department. However, it would have been impossible to attain this objective without the encouragement, understanding, and cooperation of the President and Board of Trustees. In concluding this article, it is indeed a pleasure to make grateful acknowledgement of their assistance.



▾Fig. 14. Seismic Recording Truck.

HUGOTON GAS FIELD OF OKLAHOMA AND KANSAS

By

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and

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ABSTRACT

The stratigraphy of this region in the southwestern corner of Kansas and the Panhandle of Oklahoma is discussed briefly with especial emphasis on the members of the Big Blue Series of the Permian System, Wreford to Herington inclusive, which bear gas. Stratigraphic cross sections are given. A structural contour map of the entire district shows the location of over three hundred gas wells and the elevation of the top of the Herington limestone in each.

Production statistics include the present open flow and rock pressure and the total withdrawals to date.

INTRODUCTION

This paper treats the area of the nine counties in the southwestern corner of Kansas and the middle county in the Oklahoma Panhandle. The greatest detail is known for the central part of this district, including southern Kearney, Grant, and Stevens Counties, Kansas, and Central Texas County, Oklahoma.

In this area three hundred and twenty-two gas wells have been drilled without a known failure. Wells at the edges of the field, both east and west, are much smaller in volume, however.

The gas producing area as determined by drilling is approximately ninety miles long, north and south, and from twenty to forty miles wide, east and west, and includes about 2,700 square miles, or 1,800,000 acres.

This gas producing area includes the following fields given by counties with the dates of their di...

KANSAS

Liberal, Seward County	1922
Hugoton, Stevens County	1927
Santa Fe, Haskell County	1931
Holcomb, Finney County	1932

OKLAHOMA

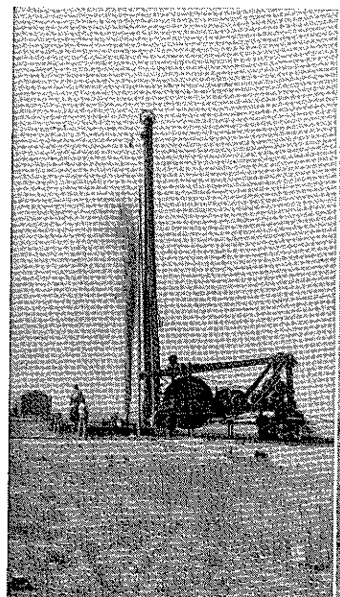
Texhoma, Texas County	1923
Guymon, Texas County	1925

It is now customary to group all of these separate discoveries under the one name, Hugoton field.

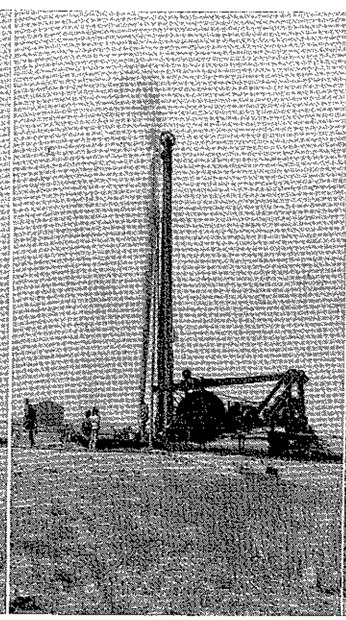
TOPOGRAPHY

The plateau level of the High Plains in this area varies from about three thousand to thirty-seven hundred feet above sea level. In common with most of the High Plains there is a gentle topographic slope from the west toward the east so that the highest elevations are in the western portion of the area.

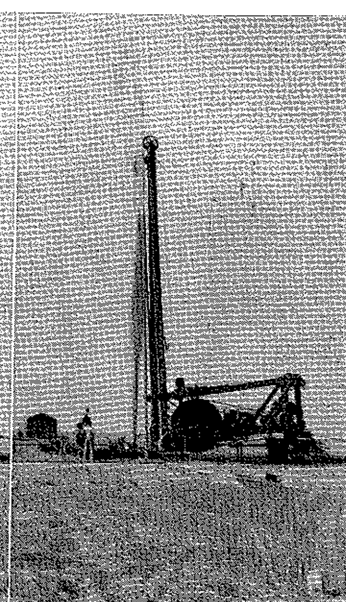
This level plateau is monotonously flat in most places but its surface is occasionally broken by wide shallow depressions called "blow-outs," caused by wind erosion. After a rain these depressions hold water for a few days or weeks, making shallow lakes, but during most of the year they are, of course, as dry as the surrounding territory.



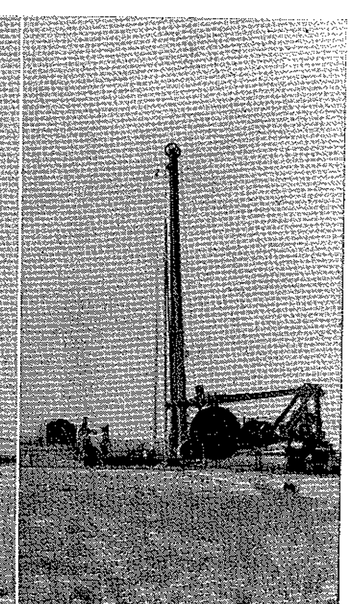
▾Well acidized—just beginning to unload fluid from well bore.



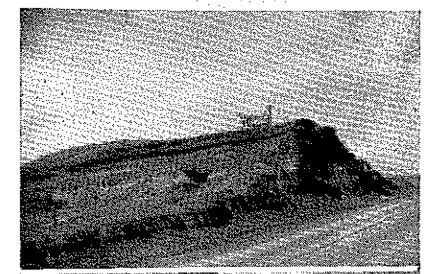
▾2nd stage in unloading.

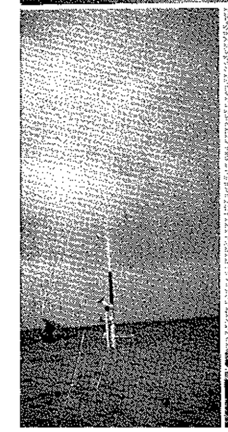


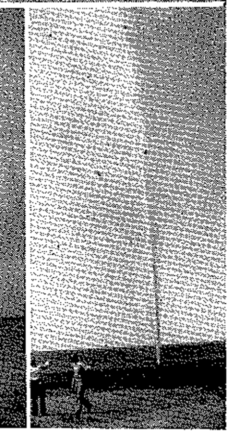
▾3rd stage in unloading.



▾Here well had eliminated the major part of the fluid at this point.







▾Top—Outcrop of red beds of end formation in Cimarron series. East of Kingman, Kansas.

▾Left—Well being blown for open flow determination. Through opening 4" in diameter open flow was found to be 12.5 million cubic feet per 24 hours.

▾Right—Fluid being blown out of well bore after acid treatment.

Three important rivers cross this region; in the northern part the Arkansas flows east near the mid-line of Hamilton, Kearney, and Finney Counties, Kansas; in the central area the Cimarron turns in a great bend from southwestern Morton County almost entirely circumscribing Stevens County toward the north and back southeastward across Seward County, Kansas; in the southern portion the North Canadian and its tributaries flow east across Texas County, Oklahoma.

These rivers have flat-bottomed valleys from one to five miles wide, with eroded slopes approaching the stream from one to two hundred feet above the valley level. The main valleys are subject to overflow practically every spring but the low terraces are seldom flooded.

Sand dunes are common in the region, reaching a height somewhat greater than the average level of the adjacent plain surface. "Blow-outs" are, of course, to be found all through the sand dune area.

The main topographic characteristic of this area is the lack of a continuous and dominant drainage pattern by minor streams. The rainfall is not heavy enough throughout the year to make the streams the chief topographic factor. The depressions end on the plain and do not continue into a major stream system. Even as large a stream as Bear Creek, which flows for forty miles across Stanton and Grant Counties, does not find its way into the Arkansas but is lost in the belt of sand dunes on the south side of that river.

STRATIGRAPHY

Details of the subsurface stratigraphy of this region are only available for those members which commonly produce gas, in the Chase and a part of the Sumner formations of the Big Blue Series of the Permian System. Only a few wells have been drilled below this level. The formations above the Herington limestone are also of less economic importance and will not be discussed fully in this paper.

PENNSYLVANIAN SYSTEM

A few wells, mostly on the edge of the field, have penetrated into the Pennsylvanian. The Vickers No. 1 Hitch in Seward County is shown on the east-west cross section. According to Ver Wiebe[3] the Pennsylvanian rocks were first encountered at 3172 feet and the top of the Topeka is at a depth of 3855 feet in this well. Other deep wells on the west edge of the same cross section, in Morton County, and at the south edge of the north-south cross section, in Texas County, Oklahoma, are plotted without an attempt at correlation of the lower beds. One well was drilled in the Hugoton field proper to a depth of 5521 feet, but the log of the lower section is not at present available for publication.

PERMIAN SYSTEM

Big Blue Series

Council Grove Group

Garrison.—A few wells in the heart of the Hugoton field have penetrated the base of the Wreford into the formations formerly grouped under the name of the Garrison shale. Some wells, as shown on the cross section, show ten feet of a soft red shale and fifteen feet of buff to light gray fine-grained crystalline limestone, somewhat sandy, and porous in the lower part. This may correspond to the Speiser shale formation and the Funston limestone member of the Bigelow limestone formation of Moore.

(In this paper we are using the names of formations and members adopted by the Kansas Geological Survey as shown by the chart "Pennsylvanian and Permian Rocks of Kansas" by R. C. Moore and others, 1934. For convenience the older names used by the United States Geological Survey in South Central Kansas are given as paragraph headings.)

Chase Group

Wreford.—All three beds of the Wreford are present and a total thickness of from eighty to one hundred feet may be found. The Lower Wreford, the Three Mile, is composed of about twenty feet of limestone, containing a small amount of chert.

The middle shale portion, apparently corresponding to the Havensville, is fifteen to twenty feet thick and composed of a reddish brown soft shale.

The upper sixty to sixty-five feet, here identified with the Schroyer, is a limestone, the top and bottom of which is buff and light gray to gray and fine-grained, the basal portion differing from the uppermost mainly in the increased porosity. In the center portion the lime is mottled, light to dark gray, with considerable light to dark gray chert.

Matfield.—The Wymore shale, Lower Matfield, and the Blue Springs shale, Upper Matfield, are represented by thin breaks of highly colored shale, often reddish brown. Both horizons are remarkably persistent. Locally the Wymore may be twenty feet or more in thickness but usually both Wymore and Blue Springs are each about ten feet thick.

Between these two shales may be found the Kinney limestone, corresponding to Middle Matfield. It is between ten and forty feet thick. Although some porcelaineous chert may be found near the base, the limestone is fairly pure. It is buff to gray in color, usually fine-grained and sometimes fossiliferous.

Barneston.—Between one hundred and one hundred and fifty feet of limestone must be assigned to the Barneston formation. Come chert is scattered throughout the entire formation and it does not seem practicable to divide the Florence from the Ft. Riley on the basis of the chert beds, although the lower part of the Florence is undoubtedly more siliceous. Since there is a red shale from five to ten feet thick about forty feet below the top of the formation, we are assigning this bed to the Oketo, making the upper forty feet Ft. Riley and the lower one hundred feet Florence. Another shale occurs locally within the Florence.

The Florence is therefore the thickest and most persistent and important limestone in the Hugoton field as a stratigraphic marker. It is usually a light to dark gray crystalline limestone with associated fossiliferous white to gray chert. It is sometimes coarse-grained and porous and often bears gas at more than one horizon in the formation. It varies in color from dark gray to buff. Locally the upper part of the Florence shows definite sandy characteristics. The chert is variable,

[3] Walter A. Ver Wiebe, "Oil and Gas Resources of Western Kansas," *State Geological Survey of Kansas Mineral Resources Circular 10*, (1938) Vol. 39, No. 7.

being frequently dull or cream to buff in color. Fragments of fossils are found, including spines, fusulines, and pieces of coral.

The Oketo shale may easily be overlooked, but a few feet of it is usually to be found in a careful examination of the samples. It is usually red or gray in color.

The Ft. Riley is a granular buff limestone, pisolitic in many samples. It may be argillaceous or locally arenaceous. This is an important gas bearing horizon and an increase in the size of the well is often found at this level. While chert is not common, some siliceous material may be found locally even high in the formation.

Doyle.—The Holmesville, Lower Doyle, is a persistent red bed with mottled green and red or brown shale, sometimes slightly calcareous. The Towanda limestone, Middle Doyle, is practically always present. It is between ten and fifty feet thick, a light to dark gray mottled coarsely granular formation, inclined to be porous. It bears gas in many wells.

The uppermost Doyle, or Gage, is quite variable in thickness, ranging from five to thirty-five feet. It is usually a gray calcareous shale, sometimes somewhat flaky in appearance. Locally it is reddish brown and iron-stained.

Winfield.—In this area the Winfield cannot be satisfactorily separated into members. It probably includes the Luta and the Cresswell limestones and may also include the Grant shale and Stovall limestone horizons, although no persistent shale has been observed at this level. The Winfield is from thirty-five to seventy feet in thickness. It is a granular and porous gray limestone, mottled in many places, and occasionally bearing chert, especially in the upper part. It contains calcite and is often crystalline in nature. Fragmentary fossils are not uncommon, especially in its middle and upper portion. It may be noticed on the east-west cross section that the Winfield thickens toward the east.

The Winfield is undoubtedly the most important gas bearing formation in the Hugoton field. In some wells a natural flow of five to six million cubic feet per day is found in its uppermost portion. In other wells as many as three gas pays are found throughout the formation.

Sumner Group

Enterprise.—The individual members of the Enterprise can be differentiated in many wells but in some regions the Odell shale is not recognizable and the Krider limestone is merged with the underlying Winfield. Usually the overlying Paddock shale is separated from the Herington limestone.

The total thickness of the entire group—the Odell, Krider, and Paddock—is from ten to twenty-five feet. In numerous places there are small quantities of gas in the Krider limestone.

In samples the Odell member is a red and gray shale, from a small break to about fifteen feet in thickness. The Krider is a gray limestone, usually medium-grained and porous, somewhat coarse-grained in the lower portion. The Paddock is a gray and brown shale with some anhydrite.

Herington.—In the Hugoton field the Herington limestone is about twenty feet thick. It is buff, sucrose, coarse-grained and porous, sometimes fossiliferous. Locally it contains chert, white or milky, with inclusions of spines.

The Herington is the youngest formation which commonly bears gas in this field. Usually the producing string of casing is set on the top of this limestone formation.

Wellington.—The Wellington is composed of gray shales and anhydrites with some beds of salt. About three hundred feet have been assigned to this formation by Ver Wiebe.[4] The limestones present at this level in Central Kansas are not recognizable in this region.

Cimarron Series

The Cimarron is subdivided in Kansas into the Enid, lower, the Blaine, middle, and the Upper Cimarron. In Western Oklahoma, the same names are used for the two lower groups and the term Woodward is usually used for a part of the Upper Cimarron. Above the Woodward in Oklahoma may be found the Cloud Chief gypsum and the Quartermaster formations. The above formations are included in about 1500 feet of red beds, gypsum, anhydrite, and varicolored shales and sands overlying the Wellington.

TRIASSIC AND CRETACEOUS SYSTEMS

There are scattered outcrops of Triassic rocks in this area in the southwestern part of Morton County, Kansas, near Wilburton; and in Central Texas County, Oklahoma, near Red Point.

In the northwestern part of this region a few isolated outcrops of Cretaceous age may be found, especially of Dakota sandstone and Greenhorn limestone and Graneros shale on the Syracuse anticline.

It is possible that some of these Mesozoic formations are present under the Tertiary Ogallala in this area, as we indicate later in this paper.

TERTIARY SYSTEM

Ogallala Group

The surface of this portion of the High Plain is almost entirely covered by the loose gravel deposits which are known under the group name Ogallala. Grant and Stevens Counties, Kansas, do not contain a single outcrop of older formations at the surface, the entire area being covered with Tertiary Ogallala gravels and with Quaternary dune sands. The other counties have the few scattered Mesozoic outcrops previously mentioned, but even here the younger deposits make up probably ninety-eight per cent of the surface exposure.

The appearance of the Ogallala is well known. It varies, in texture from fine friable sand to coarse grit and conglomerate; in color from dark brown through tan and gray to white; in composition from pure silica to almost pure calcium carbonate, in isolated outcrops even including partially weathered feldspathic rocks.

These beds of gravel and sand are usually entirely unconsolidated and make up the general plains level without any ridge or escarpment. Locally, however, some of the layers have been cemented by percolating ground water and the addition of calcium carbonate into white "mortar beds." While these mortar beds may appear to be very distinct in a road cut or hilltop exposure, there is no regularity in their stratigraphic position since this consolidation and induration may occur at any level within the formation.

The thickness of the Ogallala is difficult to estimate since it commonly follows the pre-Tertiary topography which is not essentially different from the present topography. The same amount of continental deposition may or may not be present on a slope or in a valley. Darton[5] recognized thicknesses from 180 feet to 286 feet in the north part of this area. Bass[6] found a maximum depth of 150 feet in Hamilton County, Kansas.

Wells in this field are usually drilled to a depth of five to six hundred feet before the surface pipe is set and the size of the hole reduced. The only consideration of importance to the operator is to get to a depth safely within the "Red Beds" so that the surface water is completely shut off. It is very difficult to tell how much of this upper five hundred feet is made up of the Ogallala and how much might be of the Cretaceous or Triassic beds, similar to the patches described at the outcrop. It would appear, however, that most of this "surface" material is Ogallala.

Obviously the Ogallala represents deposits of aggrading streams from the Rocky Mountains. While it has

(Continued on page 457)

[4] Walter A. Ver Wiebe, "Oil and Gas Resources of Western Kansas," *State Geological Survey of Kansas Mineral Resources Circular 10* (1938) Vol. 39, No. 7.

[5] N. H. Darton, *Syracuse-Lakin Folio, No. 212, United States Geological Survey* (1920).

[6] N. W. Bass, "Geologic Investigations in Western Kansas," *State Geological Survey of Western Kansas*, (1926) Bull. 11.

STEMMING NITROGLYCERINE SHOTS IN OIL WELLS

By

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The design of the stemming above a nitroglycerine shot in an oil well is a problem that has been considered for some time. The economics of shooting are quite considerably affected by the decision to use either solid stemming or fluid stemming. A fluid stemmed shot may clean the hole of shot debris following shot detonation with the result that the well might immediately be put on production. Solid stemming usually confines the shot to the extent that a more or less protracted period of clean-out is necessary to remove from the hole not only the solid stemming itself, but also the shot debris. The clean-out period may stretch days into weeks or months and in addition to the cost of the tools, the deferred production might amount to a considerable item. The cost of the solid stemming itself is not excessive, but the expense of removing it in terms of both money and lost production might be high.

It is apparent that if identical results could be obtained in a given well from a nitroglycerine shot with either fluid or solid stemming those results could be achieved at a lower cost by using fluid stemming above the shot. However, there are certain mechanical limits to the use of fluid stemming; broadly speaking, four conditions indicate the use of solid stemming, regardless of the increased costs. If the beneficial results of the shot cannot be expected to pay out the increase in cost of the solid stemming, the shot should be abandoned. The four mechanical conditions which indicate the use of solid stemming are:

1. *Proximity of shot to casing shoe.* If it becomes necessary to place the top of the shot within a few feet of the shoe, solid stemming is necessary to protect the shoe from damage. With solid stemming, wells have been shot to within three or four feet of the shoe without damage. The minimum distance between the top of the shot and the casing shoe for a fluid stemmed shot will depend upon the amount and concentration of explosive, amount of cement behind the casing, relative size of casing and hole below, etc. Experience with fluid stemmed shots will eventually develop information which will permit the determination of the minimum distance between the top of the shot and the casing shoe, that may be used without damage to the shoe, but it is unfortunately true that the development of that experience is expensive because the lower limit may only be identified by a damaged shoe under given conditions.

2. *Physical properties of the casing.* Regardless of quantity of explosive, distance below the casing shoe, explosive concentration, or any other consideration, a fluid stemmed shot below lap-weld casing is always attended by considerable hazard. Fluid stemmed shots under lap-weld pipe may open the welds in one joint at any point in the string or may open the welds in several hundred feet of pipe in any portion of the string. The use of solid stemming over all nitroglycerine shots placed in the open hole below lap-weld pipe is the only policy that will give any assurance of success.

3. *Effectiveness of explosive.* It is fairly obvious that a given quantity of explosive will develop more disruptive force to be expended against the formation if the products of explosion are adequately confined. Whether it would require twice or twenty times as much explosive as used in a confined shot to develop the same effectiveness in a fluid stemmed shot is a matter of conjecture. Whatever the relationship between the two, some reduction in explosive costs can be effected by the use of solid stemming. However, the added cost of cleaning out the solid stemming is usually much greater than the cost of two or three times the amount of explosive that would be used if the shot were placed under fluid stemming.

4. *Development of maximum effectiveness of explosive.* When shooting opposite a tough dolomite in an otherwise dry hole, it might become advisable to direct the maximum energy against the formation regardless of costs: any other impact would be futile. Under those conditions the use of solid stemming would be indicated so that the shot energy would not be dissipated up the hole.

If for any reason solid stemming has been decided upon, the design of the stemming itself is quite important and will be influenced to some extent by the reason for its employment. If the object of the stemming is to increase shot effectiveness, very little material may be needed because of the time factor involved in the explosive detonation. Everyone is familiar with the consequence of firing a shotgun with the slightest bit of snow, stalk of straw or other obstruction in the barrel. In a similar manner, a small obstruction in the well bore above the shot will increase the effectiveness of the explosive on the confining rock of the open hole. Liquid nitroglycerine will burn at the rate of 23,600 feet per second and hence the length of time necessary for a 40 or 50 foot column of explosive to completely detonate is exceedingly short. The force necessary to accelerate whatever stemming is in the hole to a high velocity in such a short period of time is a measure of the impact delivered to the formation and it may be seen that even a few feet of loose sand or pea gravel in the hole above the shot would, by virtue of both the mass and friction of the material with the wall of the hole or the casing, cause the deliverance of a tremendous blow to the formation.

Each unit volume of nitroglycerine will produce 749 times its own volume of permanent gases in addition to vaporizing for a brief period the water of combustion, and when both the permanent and temporary gases are raised momentarily to a temperature of above 3000 degrees C the momentary gas pressure may be high. It is usually these gases which unload the hole in a fluid stemmed shot with such spectacular flows of fluid, but it may be seen that by the time this phenomenon manifests itself the desired effects of the explosive are, relatively, long over. Increasing the effectiveness of a shot, therefore, requires a relatively small amount of solid stemming and may not of itself require the complete confinement of the explosive.

The protection of casing usually requires a much higher degree of shot confinement. Strings of casing have been damaged in the shoe even when solid stemmed with the expressed intention of preventing damage to that shoe. On the other hand, shots have been placed and fired without damage which in the light of present information would seem almost predestined to casing damage. Unfortunately, comprehensive and exact records on the details of shot placement and the reactions of the stemming in the casing at the time of detonation are very few, hence it has not always been possible to evaluate all of the factors which might have contributed to the damaging of the casing. Records now in use for each individual shot should in time establish a background of information which will permit the design of solid stemming for all shots which will assure the proper degree of confinement for each nitroglycerine shot placed. At present it is nearly always necessary to use considerable more stemming than actually needed because of the need to protect the quite considerable investment in an oil well and because the lower limits of stemming requirements are only determined by failure. A more exact understanding of requirements should result in a reduction in quantity of materials used with resultant economies in both materials and clean-out time.

The use of solid stemming over nitroglycerine shots in oil wells is a relatively recent innovation, advanced in the main by the explosive manufacturers themselves even though it meant a reduction in the amount of explosive needed to accomplish a desired result in a given well. It has however, made possible the shooting of other wells which would not have been susceptible to shooting with fluid stemming. The experience gained by the explosive companies in mine and quarry blasting provided a sound basis for advocating solid stemming, but whereas in that type of work a reduction of a few pounds of explosive per shot by the use of adequate stemming, or tamping, would, in time, result in a very definite saving to the mine or quarry operator, in oil well shooting the decision to use one hundred or three hundred quarts of nitroglycerine is usually predicated on hole diameter through and extent of the pay section to be shot. In addition, as above pointed out, an economy in explosive by the use of solid stemming might not result in an overall economy because of the expense and hazard of cleaning out the solid stemming. The small diameter oil strings of casing prevalent today necessitate the use of small tools through that casing, and if cable tools and a sand pump are used to remove the solid stemming, as is the customary procedure, the time necessary to clean out may be long and in addition there is always present the hazard of some of the material lodging between the casing and the tools and sticking them. There are instances, however, when these increased costs and recognized hazards must be accepted and solid stemming used because there is no other method of shooting the well without inviting certain disaster to the well equipment. This is particularly true in the case of a non-producer which must either be made to produce or must be plugged and abandoned. If there are only a few feet of pay open below the casing shoe, a very nice problem in solid stemming design is presented.

Due to the facts that: solid stemming is relatively new; records of shots have not been too enlightening in the past; and the opportunity is not given to any one man to be familiar with more than a fraction of the number of shots solid stemmed, general and categorical statements might reflect upon both the narrowness of a given individual's field and the fallacy of his deductions from observed phenomena. With full realization, therefore, of the criticism that may result, with the qualifications above set out, the author states that in his experience no shot which was completely confined has ever damaged a string of casing and no shot which ever did damage a string of casing was completely confined. The logical deduction from this is that complete and adequate protection to a string of casing can be assured by complete confinement of the shot.

Under pressure from various operators and technicians, men engaged in the shooting industry have attempted to develop empirical formulae for the determination of the proper amount of solid stemming for all nitroglycerine shots under all conditions. If it were possible to develop such a control, damage to casing would be sharply reduced in routine shooting. It is obvious that complete confinement is not necessary to protect every string of pipe; a 200 quart shot 100 or 125 feet below seamless steel pipe may be fluid stemmed with complete assurance while on the other hand, the same shot placed in the same manner below lap weld pipe might cause serious damage. It is also obvious that a 200 quart shot 5 feet below any shoe would undoubtedly damage that shoe. Experience has shown that casing is much more susceptible to damage if it is swung and cemented in a large diameter hole open to total depth than it would be if the casing were landed on a shoulder with a hole drilled through that casing of the approximate internal diameter of the casing. In other words, if a 7⅞" hole were open to total depth and 5½" O.D. casing were swung and cemented 100 feet off bottom, considerable more care would have to be exercised than if the 5½" O.D. casing were swung and cemented but a few feet at most above the point where the drilled hole had been reduced to 4¾". Quantity and concentration of explosive undoubtedly should affect any solid stemming design, but the quantitative affectation is obscure.

The single factor in solid stemming design which is most generally overlooked and which the author considers of paramount importance is the character of the rock being shot. For a given quartage and concentration of explosive, placed in a similar manner with respect to distance below the shoe and at a comparable well depth, 100 feet of pea gravel may completely confine a shot in a given sand while 500 or even 600 feet of pea gravel above the same shot in a tough dolomite may permit the fluid in the casing above the solid material to spray in a solid stream over the crown blocks for many minutes. Reasoning from effect back to cause, it would appear logical that if the shot is to be confined, the stemming must display a greater resistance to impact than the formation; if the formation is tougher than the stemming, the energy of the shot will be dissipated up the hole with somewhat less disruptive action on the formation than would occur if the shot were completely confined. In other words, the energy developed by the shot will be dissipated along the lines of least resistance, and if this be the stemming, then the shot will not be confined, but if the stemming has a greater resistance to impact than the formation, then the shot will be confined. It is obvious that the relative resistance to impact of the formation and the stemming is not a function of the quantity nor concentration of the explosive. Hence, any empirical method of determining the amount of solid stemming as a function of explosive quantity or concentration may well be questioned.

It should be restated that complete shot confinement is not always desirable, but should it be, it can be achieved by predicating the amount of stemming on the character of the rock to be shot. Mathematical or laboratory approaches to the problem do not have much promise; even though the impact resistance of each and every producing rock could be determined, the impact resistance of solid stemming is of necessity indeterminate, and the evaluation of one without the other is futile. A very typical solid stemming construction might consist of an umbrella bridge or cave catcher to start the bridge above the bomb shell, from one to twenty feet of broken brick or sewer tile to wedge and support the overlying material, then from one to ten yards of pea gravel. The pea gravel may be replaced with sand or cement under cer-

(Continued on page 458)

ROTARY DRILLING MUD

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Introduction

Improvement in methods of drilling and equipment during the last decade has encouraged deeper drilling for oil. With the deeper drilling of wells, more attention has been directed toward the factors which materially affected the costs. Among these factors was that of drilling mud which represented a considerable portion of the cost of drilling. As a result of scientific investigation the cost for drilling mud has been greatly reduced. The improvement in drilling mud has also resulted in increasing the drilling speed.

Owing to the fact that most of the theoretical conceptions of drilling mud are controversial, only the practical side will be discussed, based principally on California practice.

Purpose of Drilling Mud

There may be some readers who are unfamiliar with the manner in which drilling mud is used in rotary drilling. Therefore, the following brief explanation of its use is presented.

The mud is pumped from a suction pit or suction tank (Fig. 1, B) into the rotary hose and kelly down the drill pipe and out through the holes in the bit. The holes are so located that the mud stream is directed against the cutting edges of the bit. The mud flows up through the annular space between the drill pipe and walls of the hole to the surface. It is then conveyed by means of an overflow pipe (Fig. 2) from the casing to the settling ditch, flows through the ditch to the vibrating screens (Fig. 3), and then through a ditch (Fig. 1, A) to its origin, the suction tank.

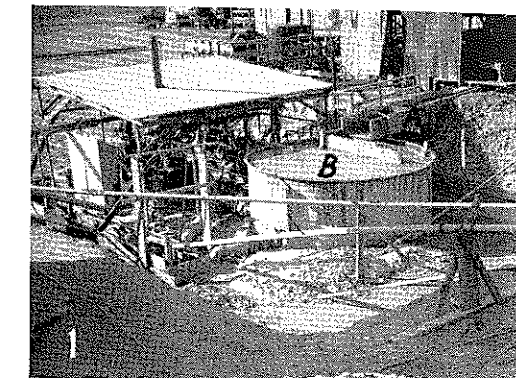
Some of the most important reasons for using drilling mud are as follows:

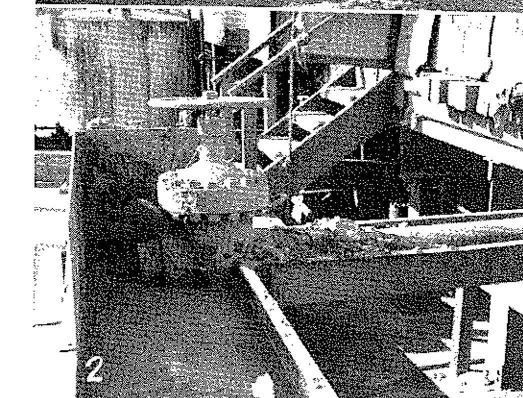
1. To convey drill cuttings to the surface and to hold the cuttings in suspension during periods when circulation has been suspended thus preventing settling around the drill collars and possibly sticking the drill pipe.
2. To hold back oil, gas, and water and possibly plastic formations by maintaining a sufficiently great fluid head to prevent their flow into the well.
3. To plaster the walls of the hole, consolidate loose formations, and thus prevent caving.
4. To aid drilling by keeping the bit clean and cool and also by its hydraulicing effect when passing through the holes of the bit.
5. To act as a lubricant between the drill pipe and the walls of the hole.

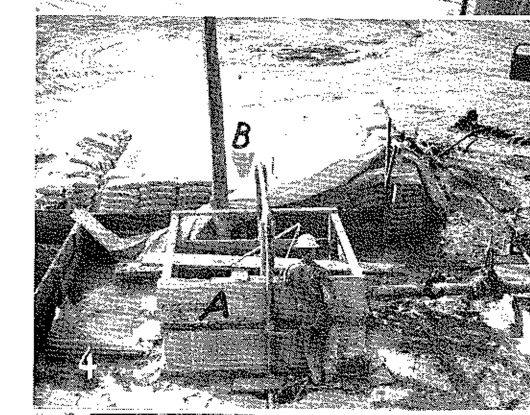
Materials Used in Making Mud

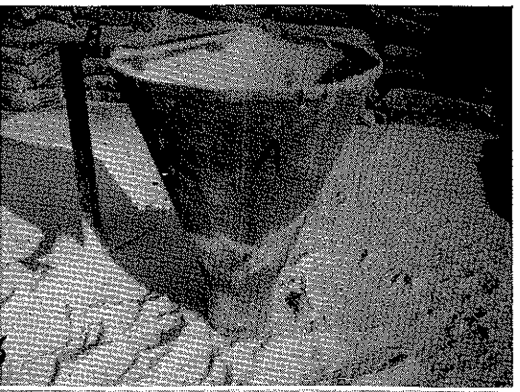
Natural occurring clays possessing suitable properties are used to make drilling mud by mixing the clay with water to the desired viscosity. The clay is ground to facilitate mixing. The mud becomes mixed with formation made mud after being put into service, i.e. when clays are drilled through they mix with the mud to a variable degree, resulting in a more viscous fluid which must be diluted with water in order to maintain a suitable viscosity. Thus drilling mud becomes a mixture of the original mud and any formation drilled through which disintegrates sufficiently to remain in the mud.

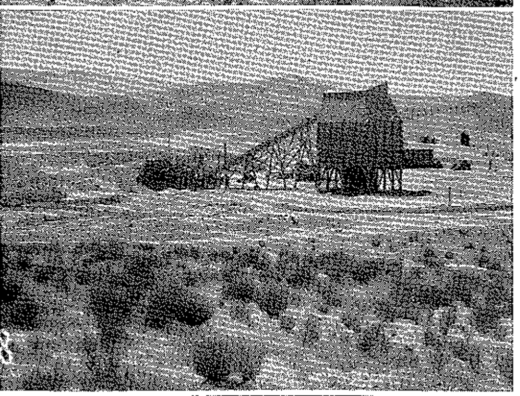
When a clay or a mixture of clay and hole made mud does not make a mud of sufficient density, heavy ma-

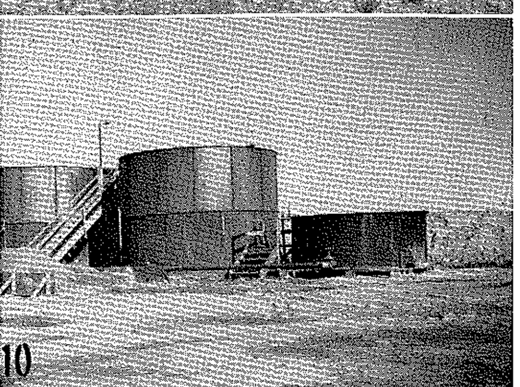


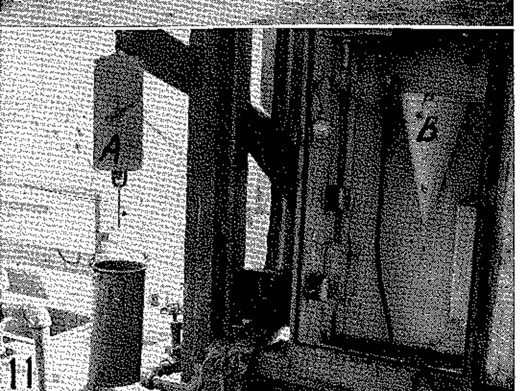












terial such as finely ground barytes, hematite, or limestone is added to increase its density.

Clays produce muds weighing from 64 to 90 pounds per cubic foot, depending on the quantity of colloidal particles present in the clay and on the physico-chemical condition. The smaller the quantity of colloids and the more they are dispersed, the heavier the mud can be made. Generally those clays should be used which will produce mud several pounds in excess of the weight required because muds tend to become thicker with use, requiring dilution with resulting loss of weight.

Many clays contain salts which are harmful in drilling fluids because of their effect on colloidal dispersions. The water used to mix with the clay should also be as free of salt as possible.

Drilling mud is usually mixed at the well by means of a jet mixer. A pump is used to circulate water and mud from a mixing pit (Fig. 4, A) or a mixing tank (Fig. 5, A), through the jet located at B in Figure 4 or through the jet in bin (B) in Figure 5, and back to the pit or tank. Clay is added slowly into the jet until a fluid of desired viscosity is secured. Figure 6 shows hopper (A) located over a jet and table (B) with paper bag cutter. This is used when clay or weighting material is packed in paper bags.

Figures 7 and 8 show drilling clay grinding and storage plants. Figure 9 is a clay deposit which is being worked.

Mud is stored at the well in tanks such as are shown in Fig. 10.

Mud made from clay costs from 15 to 65 cents per barrel, depending on the fluid yield and price. Weighted muds cost as much as $5.00 per barrel, depending on the constituents used and the weight required.

Testing Apparatus

Routine testing and control of mud can best be accomplished at the well because conditions change very rapidly at times. Automobiles equipped with various mud testing apparatus can be used to advantage to cover several wells which may be widely separated. Of course, a certain amount of testing apparatus should be kept at each well so that routine tests such as sand, viscosity, weight, and temperature can be made every hour by the crew.

Viscosity Measurements

The viscosity of drilling mud is determined in the field by means of the Marsh Funnel (Fig. 11, B). The time of efflux of a given quantity of mud is measured and reported in seconds. Several different methods are used. In one, 500 cc. of mud are poured into the funnel and the time of efflux determined. Other methods consist of pouring 1500 cc. into the funnel and measuring the time of efflux of 500 cc. or 1000 cc. The second method (1500 cc. in, 500 cc. out) is the most suitable for all conditions because if the mud has a high viscosity not all of it will run out when using the 500 cc. in and out method and this is sometimes true with the last method (1500 cc. in and 1000 cc. out). However, the first method is most commonly used in California with the third method next in popularity. The mathematics of flow under a variable head is of course complicated. The Marsh Funnel viscosity is an arbitrary number which is peculiar to this instrument and it cannot be converted into other units of viscosity. An instrument for determining viscosity should preferably be of simplest geometric design so that the measurement can be simplified. Drilling mud is not a Newtonian liquid and the mathematics of its flow are not thoroughly understood, except that its viscosity-shear relationship is not a constant as it is for true liquids.

There are several other instruments used to determine viscosity but they are usually used in the laboratory. Among these are the Stormer Viscosimeter, MacMichael Viscosimeter, and various modifications of these instruments.

Marsh Funnel viscosities used in the field based on the most commonly used method of 500 cc. in and out, vary. In top hole drilling viscosities of 22 to 40 seconds are used with an effort being made to maintain the viscosity less than 30 seconds. The viscosity varies from 30 to 200 seconds when drilling in hard shales and sands. Some operators attempt to maintain a viscosity of 30-40 seconds in hard digging, while others permit the viscosity to go much higher.

The importance of viscosity is often over emphasized. The influence of viscosity on drilling speed in hard formations is controversial. It affects circulating velocity and sand content and if the quality of the mud is known, it serves as an indication of the ease of running light weight equipment such as survey instruments, starting circulation, and securing successful cementing jobs.

Viscosity is controlled by adding water and chemicals.

Density Measurements

The weight of drilling fluid is determined in the field by the following instruments:

1. Mud bucket with scale (Figure 11, A) which consists of a 1/10 cubic foot bucket into which the mud is placed for weighing. A gallon bucket is sometimes used instead of the 1/10 cubic foot bucket.

2. Hydrometer (Figure 12), consisting of a cup which is filled with the mud to be weighed and is then attached to the graduated stem and the assembly is then placed in a container of water. The depth to which the hydrometer sinks is observed on the graduated stem.

3. Mud Balance (Figure 13), which has a cup with a lid on one end of the beam. The cup is filled with mud, the lid is replaced, the excess mud being forced out through a hole in the lid. The mud on the outside of the instrument should be washed off before balancing the beam.

All of these instruments should be carefully checked before using by setting them to correctly weigh a fluid of known weight, such as water. The density of the mud is recorded in pounds per cubic foot, or pounds per gallon, and sometimes as pounds per square inch which would be exerted by a mud column 100 feet in height.

Mud densities usually fall within the limits of 70-95 pounds per cubic foot. Muds weighing 75-85 pounds per cubic foot are adequate to hold back formation fluids in the deep San Joaquin Valley Fields. Muds weighing 85-100 pounds per cubic foot are sometimes required to hold back formation salt water at Wasco and Kettleman Hills.

Sand Content Measurements

Sand increases the density of mud. It causes pump wear and has a tendency to increase the water loss and cake thickness. It is controlled by lowering the viscosity and initial shear value so the sand can settle out in the ditch. Vibrating screens remove coarse sand.

Sand content is usually determined in the field by elutriation. Figure 11 shows an elutriation apparatus in the cabinet. The water reservoir, the bottom of which can be seen in the upper part of the picture just to the left of the Marsh Funnel (B), is equipped with an overflow and is kept full of water while making a test. A brass tube conveys the water downward through a jet which is placed in the elutriation tube to within ¾″ of the bottom. The elutriation tube is placed in clips near the bottom of the cabinet. A similar apparatus is shown in Figure 14. The principle of the elutriation apparatus is to wash out the minus 200 mesh sand and clay. The remaining plus 200 mesh sand is measured volumetrically in the graduated elutriation tube. This is accomplished by placing 100 cc. of mud in the 250 cc. elutriation tube, the tube is filled with water and the contents shaken. The elutriation tube is then placed in the clips with the jet projecting in the tube as previously explained. The water is only partially turned on until the fluid in the tube is nearly clear, at which time the water is turned on full force. The velocity of the water is such that the minus 200 mesh sand is washed out. The velocity of the water in the elutriation tube should be 4.9 millimeters per second.

The sand content can be determined by other methods such as screening, centrifuging, and settling, but these methods are not so commonly used in the field.

The sand content may be 3-10% when drilling in sandy formations and ¼-1% in shale formations.

Shear Measurement

The shearometer is used to measure shear and gel strength of rotary drilling muds in the field. It also could be used to measure viscosities, but in different units than the Marsh Funnel. The shearometer consists of a thin aluminum cylinder 3½″ long, 1½″ in diameter and weighing 2½ or 5 grams. The cylinder is placed in a vertical position in the mud and the depth to which it sinks determines the shear. Shear is measured in pounds per square foot.

Shear *(lbs./sq. ft.)*

$$= 1.04\left(\frac{W}{bR} - \frac{Wd}{bLD}\right)$$

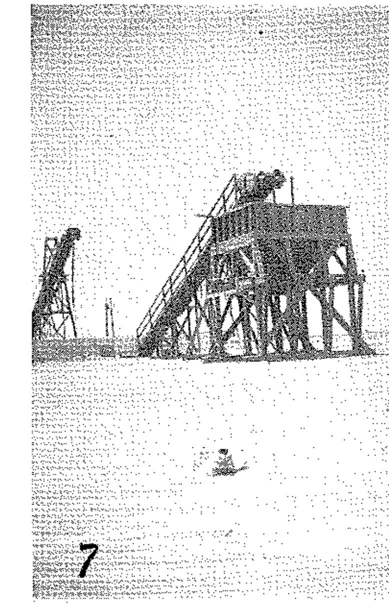
whence:

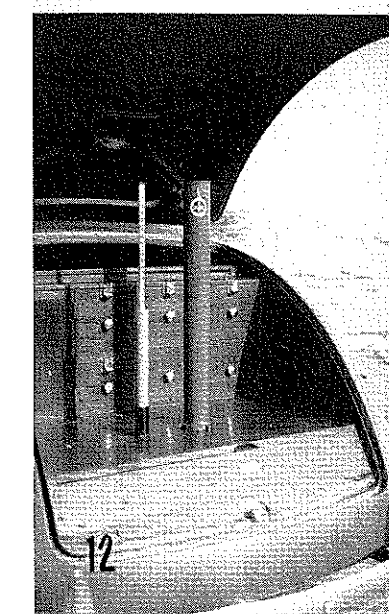
W = weight in grams of the shearometer.
d = density of mud in grams/ml.
b = circumference of cylinder in cm.
R = distance cylinder sinks in cm.
L = length of cylinder in cm.
D = density of cylinder in grams/ml.

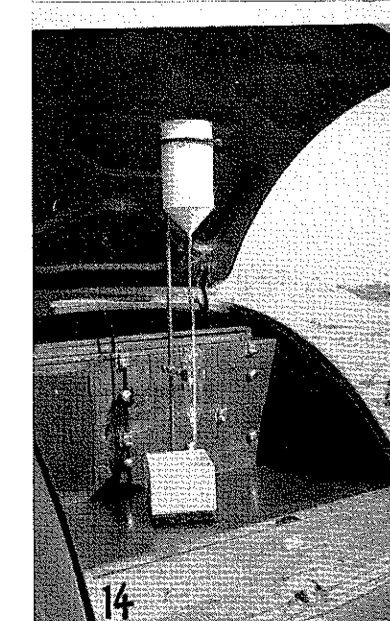
A value of *0.05 lbs./sq. ft.* is considered small and a value of *0.6 lbs./sq. ft.* is large and is the highest value which the 5 gram cylinder will determine with any degree of accuracy.

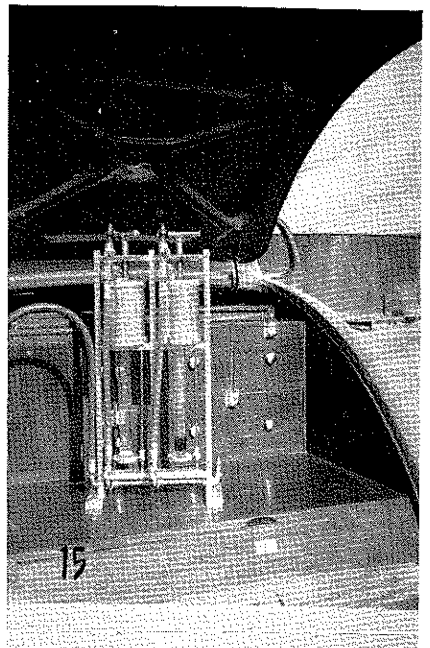
Two or more shear measurements are made to determine gel strength. The first, or initial measurement is made on mud which has just been thoroughly agitated, as when it is coming out of the overflow pipe. Subsequent measurements are made at intervals of 5, 10, 15, 30, or 60 minutes, depending on the rate at which the mud gels. If there is no increase in shear value with time, gelation is not taking place and the measurement is not a gel determination; shear measurements become gel measurements only when the mud gels.

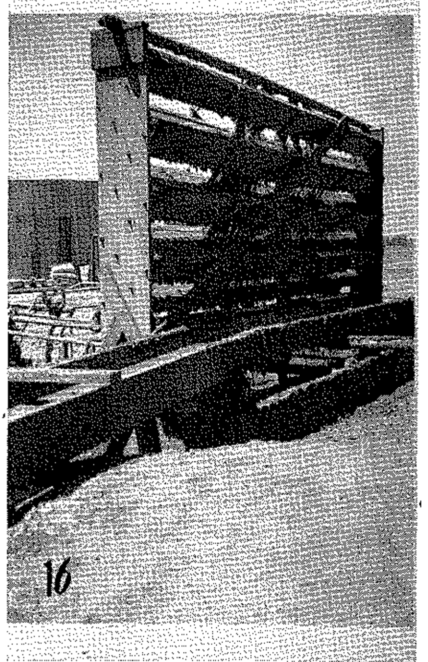
The rate or speed of gelation is determined according to the time interval between the initial and the second shearometer test which will produce a large increase in shear; i.e. if the initial shear value were *0.05 lbs./sq. ft.* and the shear increased to *0.6 lbs./sq. ft.* in 5 minutes, the rate of gelation would be excessive. If this increase required 8 hours, the rate would be considered moderate. Some

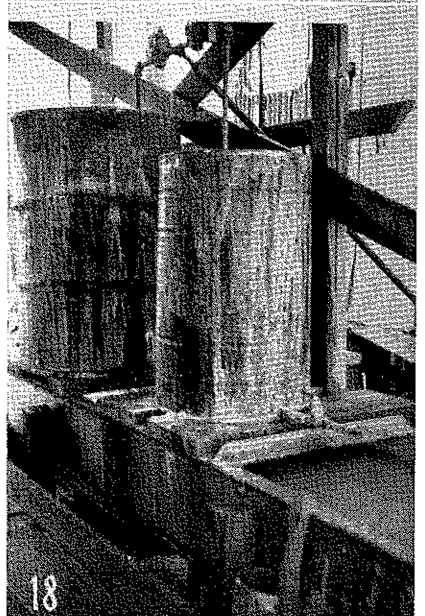












chemically treated muds with low Marsh Funnel viscosities (30 seconds) may not develop more than *0.05 lbs. per sq. ft.* in one hour.

The term, thixotropy, is applied to designate muds which develop additional shear (i.e. gel) in the subsequent (second) test and which will lose that gel strength when agitated. This cycle must be capable of occurring over and over again.

Some muds such as those which are flocculated or are low in colloids (for example Kaolin) produce a high shear in the initial test and may not show any increase in the subsequent tests. These muds are not considered to be thixotropic. The possibility should be pointed out that muds of this type may gel so quickly that it has taken place before it is possible to make a test.

Another quality of gels in drilling mud is the degree and amount of agitation required to reduce the gel strength from the value obtained in the subsequent test to that of the initial test. This might be called the durability of the gel.

A thixotropic mud is desired but it is also desirable that the gel be not highly durable, i.e. it should flow readily as soon as it is agitated.

Other instruments such as the Stormer Viscosimeter can be used to determine shear, but they are not used in the field and are not as satisfactory as the shearometer when testing muds which gel very rapidly because more time is required to make the determination with the former instruments.

The gel strength of mud is important in that it serves to support cuttings in the mud after circulation has been suspended. Excessive gel strength and excessive gel durability make it difficult to start circulation (called breaking circulation) and may prevent light weight equipment such as survey tools from reaching bottom and may cause ineffective cement jobs.

Chemical treatment reduces the shear value of a mud and retards gelling, but continued chemical treatment often results in muds which develop high shear values because the solid content of the mud increases owing to the dispersing action of the chemicals used.

Wall Building Properties

Drilling mud as such does not penetrate ordinary formations more than a fraction of an inch. The water phase of the mud will often penetrate to greater distances, especially in sandy formations.

Plastering the walls of the hole is accomplished by the weight of the drilling mud forcing the water into the pores of the formation, the water depositing the solids suspended in it on the walls of the hole in the form of a filter cake. The actual effective pressure which forces the water into the formation is the differential pressure between the formation pressure and the fluid pressure exerted by the mud column. This may be only a few pounds or may be several hundred pounds.

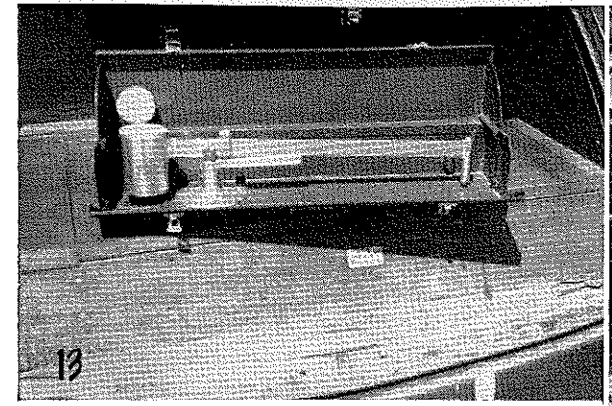
The quality of the filter cake is important in some kinds of formations. When drilling through low pressure sandy formations, the use of a mud with poor wall building properties which makes a permeable filter cake will permit large quantities of water to go into the sand. This will result in a thick filter cake being formed which causes a reduction in hole diameter. This condition causes a tight place in the hole making it difficult or impossible to move the bit past this barrier.

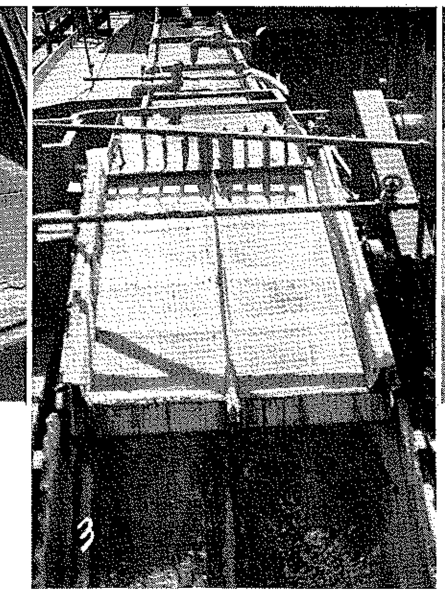
A great deal of trouble is experienced when drilling through certain shales which possess the property of swelling and breaking down when water comes in contact with them. Other shales are so badly fractured that they are unstable and slough into the hole when lubricated by water from the drilling mud. Under either of these shale conditions the use of a mud which permits only a small amount of water loss, obviates a great deal of difficulty.

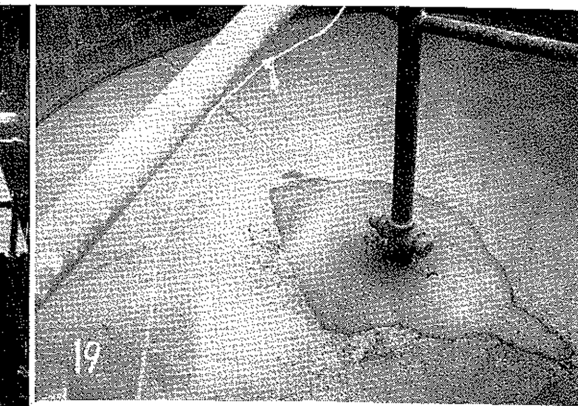
Several styles of filter presses have been used to test the water loss of muds. Figure 15 shows a two unit tester extensively used in the field. A pressure of 100 pounds per square inch is used. This apparatus consists of a cylinder of 3″ I.D. by 6″ long with removable base and top caps and gaskets. These caps fit snugly against the ends of the cylinder. The assembly is held together by means of a screw in a metal frame. The base cap has a hole drilled through it for a water outlet. A removable screen which supports a filter paper fits into the base cap. The top cap has a connection for gas or air pressure.

When ready to operate, the top cap is removed and the cylinder is filled with mud to within about ½″ of the top. The cap is replaced, the screw tightened and the air or gas pressure applied. The water loss is determined for different periods of time; usually 5 minutes and 15 minutes, and sometimes for 30 minutes and one hour. The assembly is dismantled at the end of the test and the filter cake thickness is measured.

Tests of this nature give comparative results. It would be desirable to conduct tests under actual hole conditions of pressure, temperature, and filtering medium, but this is impossible. Laboratory tests are frequently made at elevated temperatures.







A few of the most important facts concerning wall building properties are:

1. Cake thickness and water loss are high when a mud is flocculated, when the colloidal content is low, or in the absence of proper clay particle distribution.

2. Water loss and cake thickness for the same mud, other things being equal, are proportional to the square root of time. This applies only for the first hour or two. The water loss then becomes practically constant and may even increase, but it is of low magnitude.

3. Water loss is usually proportional to an exponential (less than 0.5) power of the pressure, but some muds are not appreciably affected by changes in pressure and the exponent is then zero. Pressure in excess of 500 pounds per square inch does not usually affect the water loss greatly. Clay particles are plate-like in shape and pressure tends to make the filter cake impermeable by compacting them.

4. High temperatures produce greater water loss and cake thickness.

The following arbitrary classification of cake thickness and water loss at 100 pounds per square inch pressure and at atmospheric temperature may be of interest:

Classification	*Cake thickness inches*	*Water loss Gal./sq. ft./hr.**
Excellent	less than 0.10	less than 0.06
Good	0.10 to 0.20	0.06 to 0.10
Fair	0.20 to 0.30	0.10 to 0.15
Poor	greater than 0.30	greater than 0.15

* For a 3″ filter—
0.00538 × ml. water = gal./sq. ft./hr.

It should be emphasized that a mud should not always be condemned because its wall building properties are classified as "poor." Such a mud may be completely satisfactory in certain formations which will not slough and which are almost impermeable. New clays will not meet the classification of "excellent." Muds are considerably improved by chemical treatment and blending with bentonitic clays which may be added or picked up while drilling.

Salt Content Measurement

Water soluble salts which are encountered while drilling, flocculate drilling mud. Flocculation causes a thickening of the mud. This increase in viscosity has to be overcome by the addition of water or chemicals. An additional effort of flocculation is to impair the wall building properties of the mud, and as was pointed out previously this is undesirable.

The salt which accumulates in the mud while drilling comes from drilled up formation or from salt water existing in the formation. The former cannot be prevented from accumulating but the latter can be controlled with a mud density sufficient to hold back the water.

The filtrate secured from the wall building test is titrated for chlorides. Sulphates should also be determined, although it is not usually done.

Temperature Measurement

High temperatures may increase gel strength and viscosity, although in some cases the viscosity is reduced. High temperature has considerable effect on wall building properties, as was mentioned previously.

Reduction of mud temperature is often accomplished by the use of cooling towers. These towers usually serve to degas the mud also. The cooling towers are so constructed that the mud cascades down over baffles and heat exchange is accomplished through the medium of the air. Figure 16 shows such a tower. The mud is distributed at the top of the structure through a slotted pipe and then falls down on the baffle boards. Some operators have stopped using them because of the belief that the mud accumulates oxygen when passing through the tower and that this aids drill pipe corrosion.

When drilling in the immediate vicinity of lakes or other bodies of water the mud can be cooled very easily by passing is through pipes submerged in the water.

pH Measurement

The pH value of a mud is an indication of its past history. It is especially significant when the mud has become cement cut. Much has been said about the importance of pH control, but very little benefit has been accomplished by changing pH values. The optimum pH depends solely on the past history of the mud, especially when chemicals are used and it is influenced by the kind of chemicals used. Figure 17 shows a Beckman pH meter often used for this determination.

Chemical Treatment

Chemicals are now used extensively to control the viscosity and wall-building properties of mud. Flocculated shales and salts encountered by the drill contaminate the drilling mud, causing an increase in viscosity and impairing the wall-building properties which can be at least partially overcome by chemical treatment. Chemicals used consist principally of the complex alkali metal phosphates, tannates, caustic soda, and sodium silicate.

Cement causes an increase in viscosity and impairs the wall-building properties of mud. Chemical treatment overcomes a considerable amount of the effect of cement. Chemicals used consist chiefly of sodium bicarbonate, tannates, complex alkali metal phosphates and complex acid phosphates. Sodium carbonate can also be used but it is not considered to be as effective as the bicarbonate because it does not reduce the pH.

Chemical treatment is used for overcoming heaving and fractured shales as was previously mentioned. There are several methods of treatment used. The most common consists of reducing the water loss to as great a degree as possible by means of chemicals such as tetrasodium pyrophosphate and Quebracho. The water loss should be reduced before the troublesome shales are penetrated. Chemical pre-treatment of certain clays which respond to chemical treatment reduces the water loss lower than if the mud is treated while in use. If the clay used to make drilling mud does not have a low water loss, and it is not responsive to chemical treatment, which is usually the case, the mud can often be improved when drilling through bentonitic shales. These shales may be located above the troublesome shales. Chemicals such as the complex alkali metal phosphates are used to further improve this mixture while drilling through the bentonite.

Heaving shales in the Gulf Coast fields are sometimes drilled through with drilling fluid consisting of sodium silicate and various saturated salt solutions. The object of this fluid is to prevent the shales from absorbing water.

Caustic soda and Quebracho are used to pre-treat certain clays which do not respond to phosphates.

Chemicals are added to the mud by dissolving them in water in small tanks (Figure 18) and running the solution into the mud stream in the ditch. Agitation of the mud in the suction tank is of benefit in distributing the chemical in the mud.

No attempt will be made to explain the action of chemicals in the muds because the facts are not yet thoroughly established.

Lost Circulation

Lost circulation of drilling fluid occurs when drilling through formations which contain caverns, fractures, fissures, or pores of such size that the filter cake cannot bridge the opening, thus permitting the mud to flow out into the formation.

Circulation can be regained when the cavern or other large openings are filled with mud or by bridging and plugging the openings, in the vicinity of the hole, without filling them completely with mud. If the zone which is causing the loss of circulation is a continuous one, it is desirable to attempt the latter method, otherwise an indefinite time might be required to completely fill this zone with mud.

If the zone causing the trouble consists of small openings, thick "slugs" of mud or bentonite are "spotted" opposite the formation with the hope that they will penetrate it and gel sufficiently to prevent further loss of circulation. Additional gel strength may sometimes be secured by adding chemicals to the mud. Both flocculating and deflocculating chemicals are used. Sometimes mixtures of chemicals are added which will form gels themselves. Gel strength tests should be made, adding different chemicals to the mud being used. In this way it will be definitely known how much benefit can be expected from the chemicals. Addition of chemicals for this purpose often impairs the wall building properties of the mud, especially when lime, cement, or other flocculating agents are added.

Sometimes bentonite, cement, and water are mixed so that the bentonite is present in just sufficient quantities to form a gel with the water used. About two pounds of bentonite are required per sack of cement. The bentonite is mixed with the water, and the cement is then mixed into the resulting gel. The purpose of this mixture is to produce a fluid which, although easy to pump, will not penetrate the formation very far because of its ability to stand at a high angle of repose. This is especially valuable in caverns or large fissues. When strength may be sacrificed, as in filling large caverns, as much as ⅓ bentonite may be used to replace cement. Bentonite is about 18 times as effective as set cement is alone, in increasing the volume of set bentonite-cement. The slurry should be permitted to set for 12 to 24 hours before resuming work.

In general, the greatest success can be expected by using a mud with good wall building properties and high gel strength and to this add fibrous material such as bagasse (sugar cane refuse), cotton seed hulls, redwood bark, etc. About 1000 pounds of this material is added to 100 barrels of mud and is "spotted" in the hole, left to stand for a few hours, and the process repeated several times if necessary. If a heavier mud will be required later, while this zone is still exposed, the drill pipe should be packed off when circulation is restored and sufficient pressure applied to the mud in the hole to equal the effect of the heavier mud.

Mud Reclamation

Previous to chemical treatment of mud in the ditch, mud was frequently discarded. Various attempts were made to reclaim used mud, but unless the mud was properly reconditioned with chemicals, it would, of course, not be desirable for general use, although it could be used satisfactorily in some locations. Thus, mechanical reclamation, unless augmented by chemical treatment, is unsatisfactory for present day requirements.

The practice of chemically treating the mud in the ditch has resulted in very little mud being discarded which can be economically reclaimed later.

Field Control of Drilling Muds

The derrick man or whoever is delegated to control the condition of the mud at the well, should spend most of his time at the ditch when not running drill pipe. The viscosity and weight should be determined every half hour during the first round trip of the mud, and at any other time when conditions warrant. The mud should be agitated (by whatever means is available) as soon as circulation is started. The mud in the suction pit or suction tank can be agitated or the mud can be pumped over a tower. Agitation should be continued for at least one round trip of the mud. Continuous agitation is often desirable. Figure 19 shows two jets in the bottom of a suction tank used to agitate mud.

Frequently a considerable quantity of thin, low weight mud results from the undesirable practice of washing drill pipe while pulling it. This "spot" of mud should either be taken out of the system to be returned after its weight and viscosity has been increased, or it can be reconditioned without taking it out of the system by adding thick, heavy mud into the ditch and agitating the mud in the usual manner. If all "spots" of mud with excessively variable weights or viscosities are evened out as soon as they appear, the mud can easily be kept in good condition. The use of drill pipe wipers obviates washing the drill pipe with water.

The addition of chemicals for viscosity control, when required, should be started when it is definitely known that agitation of the mud will not reduce the viscosity sufficiently. The mud should be agitated while adding chemicals whenever possible. Agitation of the mud can be discontinued about 30 minutes previous to pulling drill pipe and started up again just before breaking the kelly connection. This aids in drying the drill pipe. It is desirable to have a slightly heavier column of mud in the drill pipe than on the outside of the drill pipe when pulling pipe, so that the mud level in the drill pipe will always be below the floor level. Therefore, the mud will not spill over the floor when the joint is broken. Some operators pump in a few barrels of slightly heavier mud just before pulling the drill pipe. Stirring the mud ditch also results in securing a heavier mud. Drill pipe can be dried by inserting a patented mud displacing device into the drill pipe when ready to pull pipe. Pulling wet drill pipe results in wasting mud, and is a hazardous and disagreeable job.

A great deal of mud is wasted at some wells by using mud screens with insufficient capacity, particularly after getting back into the hole. This results from the viscosity of the mud being excessive at this time because of high gel strength. Additional screen capacity should be provided or a portion of the mud can be bypassed.

WATER FLOODING SHALLOW SANDS

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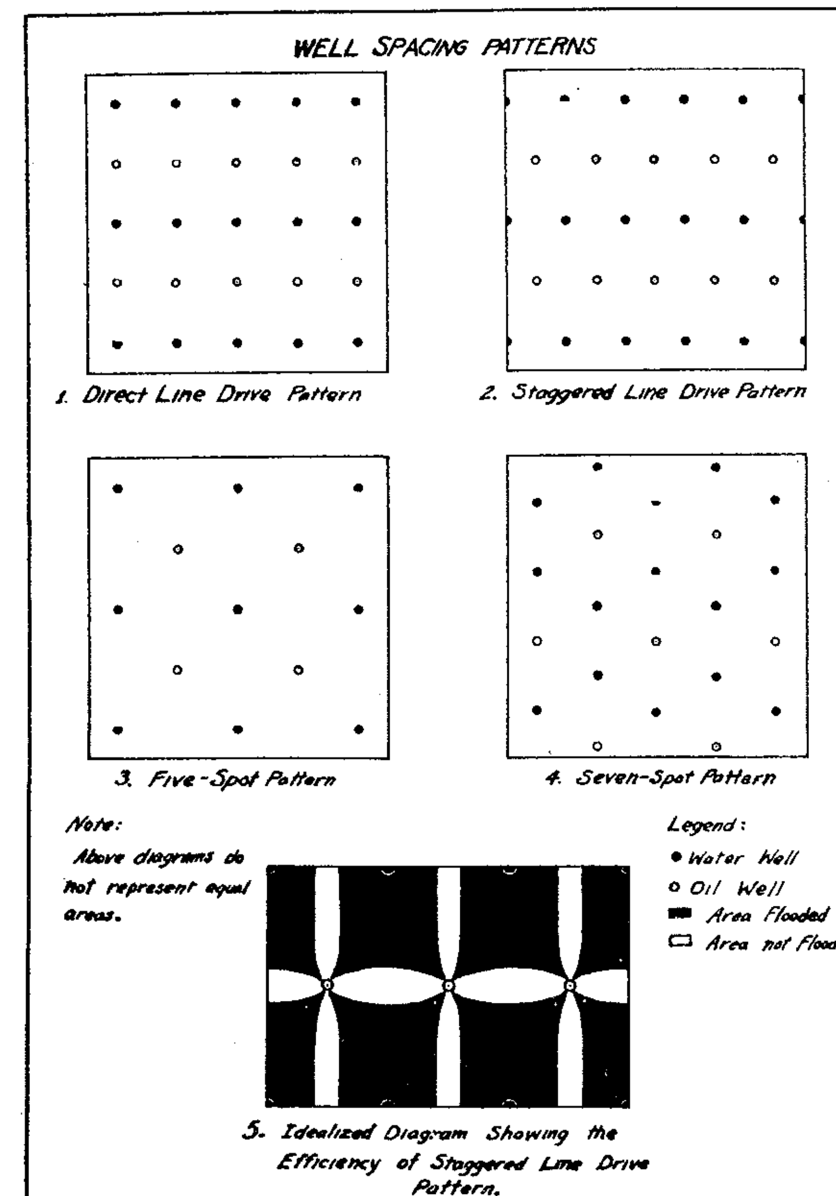
The interest of the petroleum industry in secondary recovery methods for the production of oil has increased rapidly during the past few years. The profitable productive life of many oil pools has been extended with a considerable increase in the recoverable oil by the application of secondary recovery methods such as injection of gas and air, and water flooding. The scope of this article is limited to the application of water flooding shallow sands in the Mid-Continent Area where flooding has been practiced for the past ten years. However, it was not until 1935 that the first flood of importance was started in the Nowata Field in Northeastern Oklahoma.

The recovery of oil by water flooding oil sands is essentially a mining operation, and in many respects, is more susceptible to analysis and forecasting than mining. The preliminary selection of properties can be guided by older developments which afford possible records of: (1) initial production, (2) accumulated production, (3) well logs, (4) depth to sand, (5) sand thickness, and (6) secondary recovery operations to date, if any. Should these data prove favorable for a water flooding program, the next step is to procure and to analyze a sufficient number of cores so as to determine the permeability, porosity, and oil content of the sand, and to eliminate thin sections and poorly saturated areas. The taking of cores and the subsequent analysis of them is just as important in evaluating an oil property for water flooding as sampling and assaying are to mining.

When the oil content of the sand per acre and the extent of the sand are known, an estimate of the development and the operating costs can be prepared with reasonable accuracy to provide a conservative estimate of the pay-out data and the expected return on the investment. This information is an aid to determining the value of leases, royalties, etc. It should be recognized that with the exception of the economic factors which govern the price of crude oil, *all the factors* pertinent to the valuation of a water flood program are within the grasp of the operator.

Mechanics of Water Flooding

The mechanics of water flooding to estimate the percentage of recoverable oil and the amount of water which



▾ Chart No. I.

must be injected are based on the fundamental empirical radical flow formula, developed by Wyckoff, et al.

$$Q = \frac{2\pi Kch\,(P_e - P_u)}{U\ \log_e re/ra}$$

P_u P_e

Q = quantity in barrels per day.
K = permeability in millidarcys.
C = constant to correct permeability as determined in laboratory on core samples from which all fluid has been extracted into natural conditions of sand. A constant is necessary to transpose CGS units of standard permeability unit to the foot pound system.
h = sand thickness.
P_e = pressure at external boundary.
P_u = pressure at center well.
U = viscosity of oil incentipoises.
re = distance from water well to oil well in feet.
ru = radius of well bore in feet.

The formula can be applied equally well to the determination of the flow of oil into a well or to the water input into a water well. The only two quantities to be reversed are P_e and P_u, which vary according to the point of greater pressure. There are several patterns of oil and water wells used in water flooding as shown by Chart No. 1. M. Muskat and R. D. Wyckoff of the Gulf Research Laboratory have conducted numerous experiments to determine the relative merits of the several patterns. A discussion of these experiments is not included in this paper. The five-spot pattern is used extensively in the Mid-Continent water flooding programs. Although lower in efficiency than the seven-spot and the staggered line drive, it is more easily adapted to property lines and the low efficiency is compensated for by higher conductivity which reduces the flood out time.

Efficiency may be defined as the ratio of the area covered by the flooding water to the total area. The geometry of the pattern controls this ratio. The area to be affected by the flood is that area which is covered before the water-oil interface reaches the oil wells. Since the pressure gradient is greatest in a straight line between the water well and the oil well, the maximum rate of flow can be anticipated along this line and as soon as the interface reaches the oil well, this line will present the path of least resistance to further passage of water. In other words, the flood has approached the limit of efficiency and possibly its economic limit.

Well Spacing

There are a number of factors to be considered in any development program that materially affect the choice of well spacing patterns for water flooding.

The property may contain old wells which can be reconditioned and used to reduce development costs, but occasionally the selection of such wells may hamper a uniform spacing program. The shape and the area of the lease frequently cause complications. Divided royalty interests further complicate the picture. Operations on neighboring leases may offer a barrier to the proper well spacing program.

Economic factors generally determine the proper well spacing for a given property. Among the factors to be considered are the cost to drill the wells and other development costs, pressure that can be applied, rate of oil production and the depletion of the property, the amount of oil to be recovered, operating costs, the possible variation in oil recovery due to non-uniform sand conditions, and the salvage value of the equipment.

The depth and the strength of the formation determine the maximum pressure that may be satisfactorily applied to a given formation. The effective permeability of the sand, the viscosity characteristics of the crude oil, and the pressure that can be conveniently applied determine the rate of production and the rate of depletion that can be obtained for a given well spacing. The oil recovery depends upon the amount of recoverable oil present in the formation and the volume of sand that will be effectively flooded in a given time. The volume of sand effectively flooded depends upon the effective permeability of the sand, the viscosity of the oil, the uniformity of the formation between well locations, the pressure difference applied, and the well spacing to be used. The relative value of high production rates with a large investment in wells, a short operating period, and the possible salvage value of equipment must be balanced against lower rates of production, a smaller investment in wells, a longer operating period, and possible salvage value of equipment after longer periods of service. For a given property there is usually an optimum well spacing that will provide the most satisfactory economic return on the investment.

From the fundamental radial flow formula a given oil sand of a definite thickness, permeability, and oil viscosity will take water in proportion to the pressure applied to the sand face. This relationship has been proven in practice. The limiting value of the pressure which may be applied to the sand depends on the depth of the well, or rather, the weight of the overburden; therefore, the same flood out time may be obtained with relatively wide spacing on deep sands, (1000′ or greater) as is obtained with close spacing on shallow sands where the characteristics of the sand bodies are identical.

However, a careful tabulation of operating costs against development costs will reveal a marked economy in using both the maximum pressure and the maximum spacing.

For comparison, the following projects with comparable sand conditions are approximately equal from an economic viewpoint which takes into consideration the development costs, oil recovered, and time required for recovery.

(The same permeability in each case.)

Depth	*Spacing*	*Oil in Place, Bbls. per Acre*
500′	330′	10,000
700′	377′	10,700
1000′	440′	11,400
1300′	528′	13,300

Permeability of Sand

The sand permeability next to oil recovery indicates the probable success of a flood, therefore the selection of the minimum permeability that can be flooded out with economic water-oil ratios while recycling water through washed out zones of higher permeability is important. The total millidarcy feet capacity* of the sand above any selected minimum permeability divided by the millidarcy feet below that permeability will provide a rough calculation of the lowest water-oil ratio when the sand has been flooded to the selected permeability. When the minimum floodable permeability has been selected, the oil in place figures can be revised to include only that oil contained in sections above that permeability. On sands with relatively low permeability the water input rate is low and the economic success of the project may be jeopardized due to the slow rate of recovery.

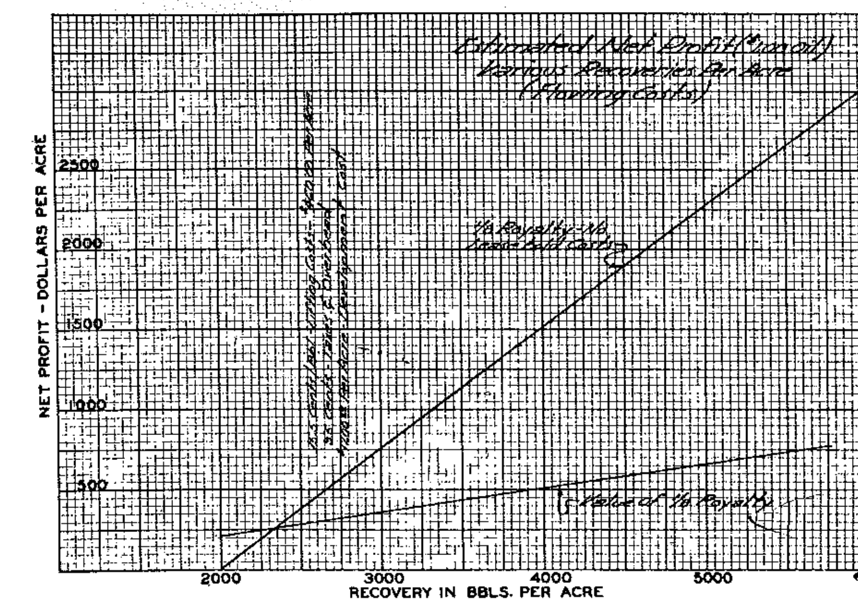
Development

The development of a water flooding project involves principally the drilling and equipping of wells and the construction of pressure plants.

The development cost is very sensitive to the well density, and the depth. For higher permeabilities or longer term flooding operations the spacing can be wider. The cost of drilling will be in the order of 60 cents to 1 dollar per foot for depth to about 1500 feet. The drilling costs per well can be kept to a minimum due to the large amount of drilling in even an 80 acre project, as the present practice is of the order of 1 well to 2.5 or 3 acres.

The completion of water input wells includes shooting with small quantities of solidified nitroglycerine (1-2 quarts per foot) and cleaning out. If a core were taken of the well and high permeability streaks are present, these streaks should not be shot in order to minimize by-passing of water. A 1½ inch tubing string with packer is set at the top of the sand and cement dumped above the packer. This method eliminates at least part of the customary casing program. Usually the well is drilled into the shale below the sand section to catch cavings, etc., in wells where the complete sand section carries oil.

* Millidarcy is a unit of permeability or rate of fluid flow through the sand. Millidarcy feet capacity is obtained by multiplying average permeability by the thickness of the sand in feet.



▼Fig. No. 2.

The oil wells are completed in a manner similar to normal shallow pumping wells. In general the well is shot, cased, and equipped with 2″ tubing. Flowing the wells thru tubing with the tubing string cemented into the sand, the same as a key well, reduces both the development and the operating costs to a point where sands with saturation too low to justify pumping can be economically produced. If the wells are pumped instead of "flowed," they are equipped with working barrels and rods which are actuated by electric motor driven individual pumping units or by a central power.

The water system is not particularly difficult to set up providing an abundant water supply is available. Streams are excellent sources of water supply, and shallow water wells are often used, also salt water produced from the deeper horizons can be treated and used.

The size of the water plant will depend on the acres to be flooded, the time to complete the flood, the void space in the sand, the permeability ratio for each acre of sand, and the amount of connate water* present in the sand. The barrels of water input required per barrel of oil produced will vary with sand permeability. Water inputs prior to maximum oil production have been in the order of 15,000 to 30,000 barrels per acre on many projects.

Water treating is practiced by many operators. The water generally is filtered and when necessary it is treated. Water must be entirely free from foreign material which might plug the sand because a majority of the input wells are completed in such a manner that mechanical cleaning out is practically impossible. The water system is generally designed for high working pressures and pressure water meters are usually installed at the key wells.

Operating Expense

The main items of operating costs are labor, fuel, well servicing, and general maintenance. Labor and general maintenance will vary more or less in proportion to the number of wells on a given acreage. The fuel item becomes increasingly important in older floods as the quantity of available gas diminishes and as it becomes necessary to handle more and more water. When large quantities of water are handled the operating costs are increased materially. For example, based on a 500 acre project, having 3000 barrels of oil per acre in place with a six year economic life, the lifting cost per barrel will vary between 15c per barrel for flowing and 30c to 60c per barrel of oil for pumping shallow wells.

Economic Prospectus

Efficiency in any industrial pursuit may well be responsible for its success or failure. This is particularly true today of water flood operations. The present price of crude, demands efficient operation for the operator to realize a reasonable profit with taxes and other costs mounting. It is therefore imperative that each operator produce a maximum amount of crude per acre at a minimum cost per barrel to be successful.

The majority of engineers have questioned the lower limit of the recovery per acre for a successful flood. The curve Fig. No. 2 shows: (1) The estimated net profit which will result from the development of shallow flood properties with various amounts of oil in place, and (2) the lower limits on the amount of oil in place under a property below which water flooding may not be considered a profitable investment in the Mid-Continent Area, based on oil selling for $1.00 per barrel. From this curve it is indicated that the economics of flooding sands with less than 2000 barrels of recoverable oil per acre in place at start of the flood is questionable.

Conclusions

Water flooding in the Mid-Continent Area is limited only to the present day engineering and operating practices.

It has been proven that water flooding can be done with a profit wherever enough oil can be recovered to pay the development and production costs and yield a reasonable return on the investment. The fundamental factors which determine recovery are porosity and saturation, which together indicate the oil in place, and the permeability. Except for the time required to complete a flood permeability has little effect. The type of pattern generally used has been the five-spot with the well spacing 330 feet. This spacing has proved advantageous in increasing the recovery coupled with a reduced pay out time on the investment. The development costs have decreased to where a typical property in the shallow producing horizons can be developed for $1,300.00 per acre.

The treatment of water has received a great deal of attention. The trend is toward the use of less chemicals and reduction of cost. The treatment of salt water has been discontinued where it is not corrosive when carried in pipe lines in the absence of air. Hydrated lime and alum are commonly used as treating agents and are used in connection with water filters and settling tanks.

The future of water flooding oil properties is dependent on factors not inherent in the process itself. The demand for oil and its products, the

(Continued on page 460)

* Connate water is that water which is found in the interstices of the sand and should not be confused with that which is commonly called "bottom hole water."

USE OF ALCOHOLIC SOLUTIONS IN SECONDARY RECOVERY OF OIL

By

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For more than twenty years the petroleum industry has realized that the oil sands of abandoned or rapidly declining fields contain large amounts of oil. This oil is being held as a film by the adsorptive properties of the sand grains and the surface tension of the oil. The amount varies with the different sands and the character of the oil, porosity of the sand, and the size and continuity of capillary openings. The recovery by pumping and later by a water drive, under the most favorable conditions, yields only from 50 to 75 per cent of the total oil. The average will be 60 to 70 per cent, leaving much of the oil unrecovered.[1]

Research work has proven that under certain conditions and proper handling, this oil film can be broken. The film may then, by its cohesion, form itself into a droplet of oil.[2] The principles underlying the use of an alcoholic solution to release the oil film may be explained by the fact that alcohol is soluble in both water and the lighter hydrocarbons present in the crude oil. Since the alcohol will combine with the lighter hydrocarbons of the crude oil, the surface tension will be reduced and thus the oil is more easily released and collects in small droplets; thence, it is forced ahead of the encroaching aqueous alcoholic flood.

It is strongly suggested that in planning a campaign for the flooding of a depleted oil sand that all the necessary information regarding the conditions to be encountered be correlated in such a way that the conditions for flooding might be made as favorable as possible and the alcoholic solution be given a chance to come in contact with the sand grains and the oil film holding the oil to the grains of sand.

A study of the field concerned should be undertaken showing the water sands, direction of drainage, cap rock, possible bottom waters, faults, arches and depressions, thickness of sands, and the probable amount of oil left in the sands. The geological structure should govern the location of the intake wells and the location of the recovery wells.

Experiments have been carried on in the Petroleum Engineering laboratories of the Colorado School of Mines by the author which show that the use of a water soluble alcohol in the flooding of oil sands will greatly increase the recovery of oil. It has been found that a one per cent solution of ethyl alcohol with water will reduce the surface tension of the oil economically and will in turn tend to form no emulsion of the crude oil forced into the recovery wells.

The equipment and procedure used in the experiments were as follows:

Two one-inch glass tubes about 36 inches long filled with Dakota sand of finer than 50 mesh each saturated with 500 cc. of 27.5 API Wellington crude oil. Each tube was fitted with one hole stoppers with glass tubes about three inches long.

The sand containing tubes were inclined at an angle of about 30 degrees and allowed to drain naturally. Then a water flood was applied to the lower end of the tube and as much oil recovered as possible at the upper end of the tube. After this, the various alcoholic solutions were applied and a record of the amount of additional oil produced was kept.

Results obtained were as follows:

From the experimental data it can be seen that: the use of one per cent ethyl alcohol with ordinary water gives 98 per cent better recovery than an ordinary water flood; the use of one per cent ethyl alcohol with salt water gives 98.4 per cent better recovery than a salt water flood; the use of one per cent ethyl alcohol with salt water as an initial flood gives three per cent better recovery than with a salt water flood plus an alcoholic flood; the use of one per cent iso-propyl alcohol with salt water as an initial flood gives 1.7 per cent better recovery than an ethyl alcoholic flood; a total of 60 to 63 per cent of the original oil present may be recovered; the use of a dilute solution of water soluble alcohol and water will almost double the amount of oil recovered by flooding with water.

Although a solution of iso-propyl alcohol gives slightly better recovery than a solution of ethyl alcohol, it has been found that a solution of ethyl alcohol is more economical.

From observing that very little emulsion is formed in the oil produced with an alcoholic flood another

(Continued on page 460)

Tube No.	Vol. of Oil to Saturate cc.	Natural Recovery cc.	Per Cent Recovery	Recovery With Water cc.	Per Cent	Recovery With 1% Ethyl Alcohol cc.	Total cc.	Total Per Cent Recovered
1	500	175	35.0	47	44.5	45	267	53.4
2	500	180	36.0	43	44.6	42	265	53.1
3	500	160	32.0	53	42.6	49	262	52.8
4	500	150	30.0	61	52.3	59	270	54.0
5	500	182	36.4	41	44.6	40	263	52.8
6	500	178	35.6	48	45.2	45	271	54.3

Av. per cent recovery by water—9.7.
Av. per cent recovery by 1% ethyl alcohol—9.5 additional.
Per cent additional recovery by alcoholic solution—98.

Tube No.	Vol. of Oil to Saturate cc.	Natural Recovery cc.	Per Cent Recovery	Recovery by Salt Water cc.	Per Cent	Recovery With 1% Ethyl Alcohol & Salt Water cc.	Total cc.	Total Per Cent Recovered
1	500	181	36.2	60	48.2	59	300	60.0

Per cent recovered by salt water—12.0.
Per cent recovered by 1% ethyl alcohol with salt water—11.8 additional.

Tube No.	Vol. of Oil to Saturate cc.	Natural Recovery cc.	Per Cent Recovery	Recovery With 1% Ethyl Alcohol & Salt Water cc.	Total cc.	Total Per Cent Recovered
2	500	177	35.4	134	311	62.2

Per cent additional recovery with 1% ethyl alcohol and salt water as initial flood—26.8.

Tube No.	Vol. of Oil to Saturate cc.	Natural Recovery cc.	Per Cent Recovery	Recovery With 1% Iso-propyl Alcohol & Salt Water	Total cc.	Total Per Cent Recovered
3	500	175	35.0	142	317	63.5

Per cent additional recovery with 1% iso-propyl alcohol and salt water as initial flood—28.5.

Iso-propyl alcohol solution gives 1.7% better recovery than ethyl alcohol solution.

CONTRIBUTIONS TO THE PETROLEUM GEOLOGY IN THE SOUTHWEST OF MATTO GROSSO, BRAZIL

Translated by
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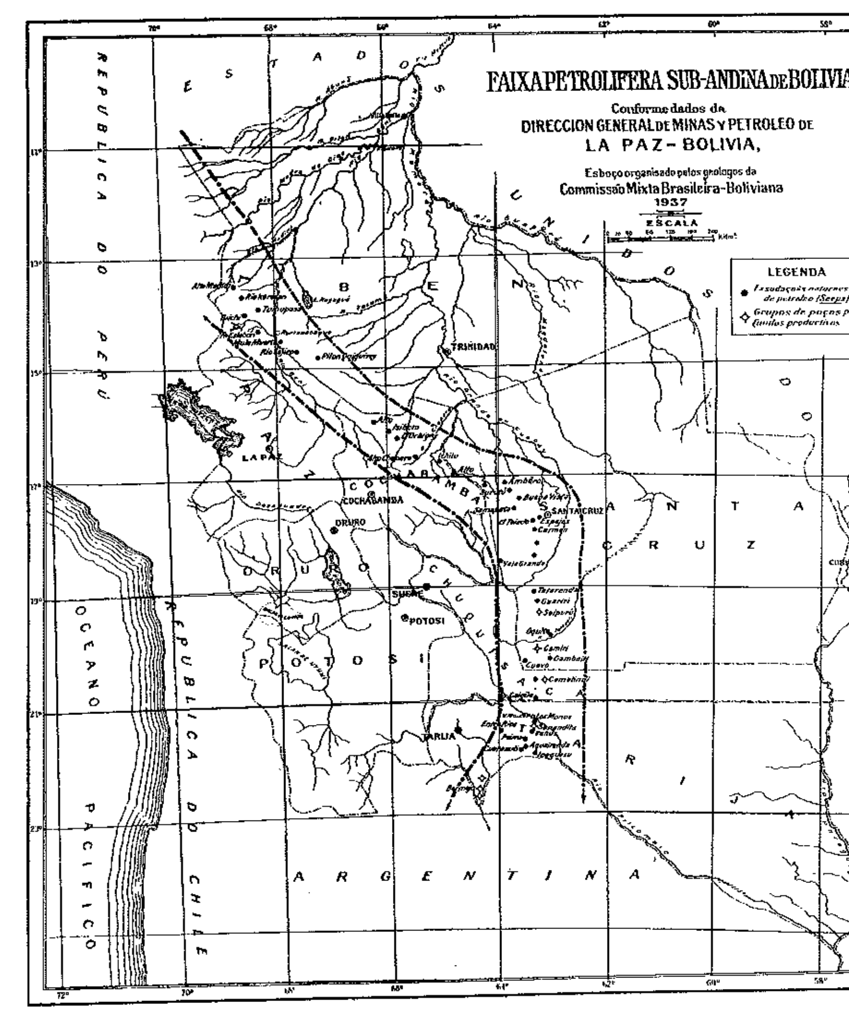
INTRODUCTION

For reasons which will become apparent probably a better name for this article would be "Contributions to the Geology of the South West of Matto Grosso" without mentioning the word "petroleum." Since 1932, owing to the "Chaco War" between Bolivia and Paraguay, which broke out on account of the existence of petroleum deposits in Bolivian territory, the "Chaco" has become very well known and always associated with petroleum. This association also suggests itself to the Brazilian people when referring to the west of the State of Matto Grosso, Brazil, due to the geographic proximity of this territory to the "Chaco Boreal" (Bolivian Chaco), since the two together form the "Central Depression of South America." This well defined depression is formed not only by Bolivian but also by Brazilian territory and extends for hundreds of square miles at an altitude of from 300 to 900 feet. (Plate I and II)

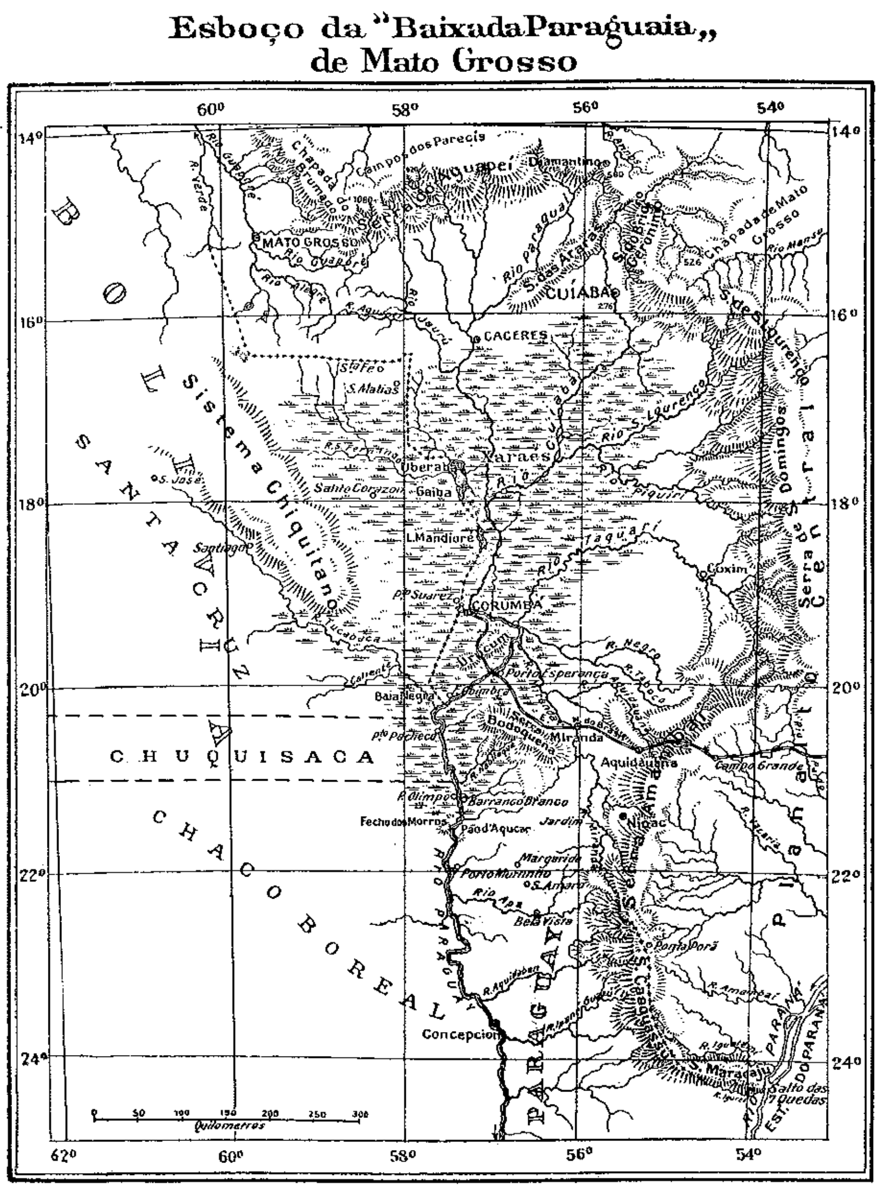
In 1936, a company encouraged by so-called geological and physiographical appearances, started work in Matto Grosso in search of petroleum. The shares of this company were eagerly subscribed for by the public, as a result of intelligent and well planned propaganda. At present it is making geological investigations in a district near Corumbá (Porto Esperanca), (Plate III), having given up a large area of land which it considers to have little possibility of oil production.

The "Dept. Nacional de Producao Mineral" (Brazilian Geological Survey) at almost the same time undertook a geological reconnaissance in Matto Grosso. As a matter of fact meagre geological data exist concerning this area, apart from some works by Evans (The Geology of Matto Grosso, Quarterly Journal of the Geological Society of London), Arrajado Lisboa, and others, all mentioned by Gerth in the bibliography attached to "Geologie Sudamerikas." The present reconnaissance is gathering data for the Federal Government for use in checking the private investigations being carried out. This reconnaissance started from the extreme south west, on the frontier of the Republic of Paraguay, in geographical contiguity with the Chaco Boreal. Evans obtained geological data for comparisons by studying, not only the Brazilian side of the basin of the River Paraguay, but also the Bolivian, in the region formerly visited by Alcides d'Orbigny (Voyage dans l'Amerique Meridionale), Count Bonarelli, and Heald and Mather, geologists of Messrs. Richmond Levering Co. Immediately following is a presentation of the preliminary results of his observations and opinions on the extreme south



▼ Plate I—Sub-Andine oil belt of Bolivia according to data from the Director General of Mines and Petroleum of La Paz, Bolivia. Map organized by geologists of the Brazilian-Bolivian Commission, 1937. Legend: Solid dots represent seeps. Open circles represent oil fields.

* Departmento Nacional da Producao Mineral, Bulletin 37, Rio de Janeiro, 1939. By Glycon de Paiva and Victor Leinz. (Original published in Portuguese). The translator recently completed a study of Brazilian oil possibilities which included the area discussed in this Bulletin. Grateful acknowledgment is made to Doctor Glycon de Paiva, of the Departmento Nacional da Producao Mineral, Brazil, for permission to publish the translated report. (Copyright reserved by the translator.)



▼ Plate II—Map of the Paraguay Basin of Matto Grosso.

west of Matto Grosso (about 30,000 square miles), considered from the point of view of petroleum resources. The senior author did not give his opinion on the rest of the northern area as he did not visit the region.

The typical rocks of the principal formations of the Brazilian side of the River Paraguay were described by his colleague Prof. Viktor Leinz. The Bolivian works are better known as there are over 60 dealing with the "Sub-andine Belt," (Plate I). Evans concludes that about 18,000 square miles of the south west represents rocks of the Brazilian Crystalline Basement outcropping in Matto Grosso, and about 12,000 square miles, a somewhat metamorphic dolomitic limestone formation, called "Bodoquena," which is still almost unstudied. Further geological and petrographic investigations are awaited before any opinion can be given as to their possibilities.

The chapters of the study by Glycon de Paiva and Viktor Leinz are:

- I "Physiographic and Geological Comparison of the Flanks of the Rio Paraguay basin."
- II Review of the "Gondwana" of the "South West of Matto Grosso."
- III Petrography of the "Serra de Maracaju rocks.
- IV The "Baixada do Paraguay" series.
- V Bodoquena Limestone.
- VI Petrography of the "Baixada do Paraguay."
- VII Geological Comparisons of Parana basin with the Sub-andine belt of Bolivia.
- VIII Conditions of Life in the South West of Matto Grosso.

Chapter I explains the reason for the interest in this area.

Chapter II deals with the sandstone of the "Serra de Maracaju" and the outpouring of basaltic lavas covering them and the permo-carbonifeious territory of Central Parana.

Chapter III is a microscopic study of the mentioned rocks.

Chapter IV considers the "Baixada do Paraguay," the peneplained crystalline shield.

Chapter V deals with an extensive dolomitic limestone formation, an area untested for oil possibilities.

Chapter VI includes descriptions of the typical rocks of the "Baixada do Paraguay."

Chapter VII compares geologically the flanks of the Paraguay basin.

Chapter VIII is an economic summary of the "South West" and its conditions of life.

This translation has been condensed into three parts as follows:

Part I Physical Aspects of the Paraguay River Basin in Matto Grosso.

Part II Geology: Consolidates the material appearing in the first seven chapters cited above and also includes material from Gerth.

Part III The inhabitants and their mode of life. Taken from Chapter VIII and includes some personal observations by the translator.

PART I

Physical Aspect of the Paraguay River Basin in Matto Grosso

To study this area properly one must first realize that there are two distinct regions. One region, the west and north of the State, is a plateau (Fig. 4) the Matto Grosso portion of the Brazilian plateau, which the "Noroeste" (railroad) crosses for a distance of 450 kilometers from the Paraná river to Jaraguá, with an elevation of from 300 to 600 meters above sea level. The other region, or the east, is the Paraguay basin, which is crossed by the same railroad, from Cachoeirao, a distance of 250 kilometers to Porto Esperanca, with elevations of 100 to 225 meters above sea level. The "Pantanal" is a small fraction of the Paraguay basin, below 110 meters in elevation, where many rivers merge to form the Paraguay. A great salt marsh, with 2 to 3 meters depth of water, has formed here. This swampy area north of Corumbá is called the "Xaraes" (shahrah-ees). In recent years this hydraulic compensation has been changed due to prolonged droughts, so that autos can travel where launches formerly had water courses six feet deep.

The only mention in literature of the south-western Pantanal is in an unpublished report by Lisboa. Milward also made a trip through this region in 1922 but published no report. The geology of the area has been briefly outlined by Castelnan a Arrojada Lisboa, who identified it with the Gondwana of Southern Brazil. The Pantanal does not extend more than 50 kilometers to each side of the Paraguay river. Summarized: The depression between the Andes and the Brazilian Plateau is composed of two distinct geological provinces, which meet in Bolivia. These are:

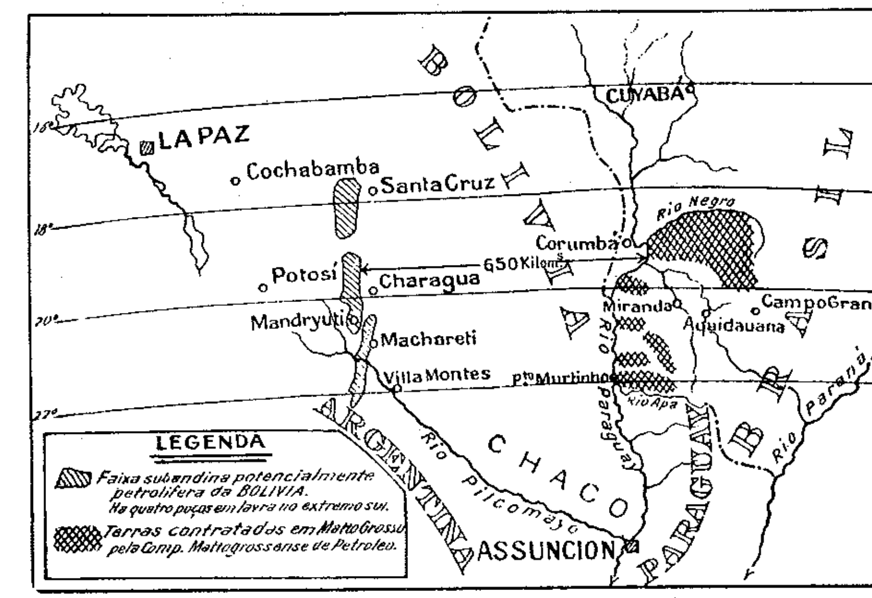
(a) The West province, or Chaco, entirely in Bolivia, consisting of thick unmetamorphosed sediments, from Devonian to sub-andine Tertiary, of marine and terrestrial origin, is a negative crustal area.

(b) The East province, or Pantanal, in Bolivia and Brazil, is crystalline, locally covered with Bodoquena limestone (which has no Bolivian equivalent) and deposits along the edges of the principal rivers. This is a positive crustal area, and probable origin of the sediments in the west province.

The Chaco (Vorland) of the Subandine shelf has neither oil seeps nor oil wells. This area continues to the west flank of the Systema Chiquitano in Bolivia. Thus the Chaco and the Pantanal are two distinct areas, geological opposites. If oil were found in south west and central Matto Grosso it would be peculiar to the locality, without *any* relation to that of Bolivia.

The distance from the Bolivian oil fields to the land in which Cia. Mattogrossense (the private oil company) is exploring is 650 kilometers. Their map should show the Sub-andine shelf as potentially petroliferous, not as oil fields being developed. Actually there are only 2 wells in Sanandita and 2 in Canieri to the north, in the Subandine belt, (Plate I). It is probable, in preparing their map, that the Spanish word "exploracion" (to explore) was taken for the Portuguese "exploracao" (to exploit), which was a serious error. In addition to indicating several areas as well locations which are outside the geological possibility, they suggested the possible extension of the Sub-andine shelf to the extreme north of Santa Cruz. The Argentine government explored this possibility with a well which was stopped in the tertiary at a depth of 1800 meters, a considerable distance above the probable oil zones.

As a last word, there should be mentioned the "oil seeps" which the "Caboclos" (hill-billies) of south eastern Matto Grosso have repeatedly described to visitors. These are of Amoguijá, Emandica, and the famous Morro do Azeite (hill of oil). These were all "iron stain" or black soil, and *not one* seep was found in all the area. The gas exudations were revealed as simple air bubbles. The well of Retiro Sao Joaquim in Amoguijá, the celebrated well of Balzaretti, after being cleaned, had no odor or show of oil, was merely clean water. An examination of the rocks adjacent reveal them to be presilurian phyllites, definitely nonpetroliferous. The bituminous schists are ordovician and cambrian micaceous shales. No oil stain could be extracted from them. The origin of the name "Morro do Azeite" lies in an old fish oil extraction plant which was here. Evidently the wish for oil has led most of the Brazilians to think of the chaco (Bolivia) as the same type of formation as the Brazilian pantanal, though they are actually unrelated.



▼ Plate III—General location of the Sub-Andine oil belt. Map by Glycon de Paiva. Legend: Single shaded portions represent potential oil producing areas. Double shaded portions are lands contracted in Brazil (Matto Grosso) for exploration.

The flanks of the Andes emerge from the area where the first oil wells are situated more than 650 kilometers west of Matto Grosso. From the foot of the Andes to the Chiquitano system the land is unexplored and only very recently has been flown over by war planes. The commercial flight is from Corumbá to Villa Montes over Santa Cruz, (Plate III). Therefore, the plain has no name. The area was traversed by a French geologist, lost in the American forest in the romantic 1830's. Alcide d'Orbigny called this the "Vorland Andino."

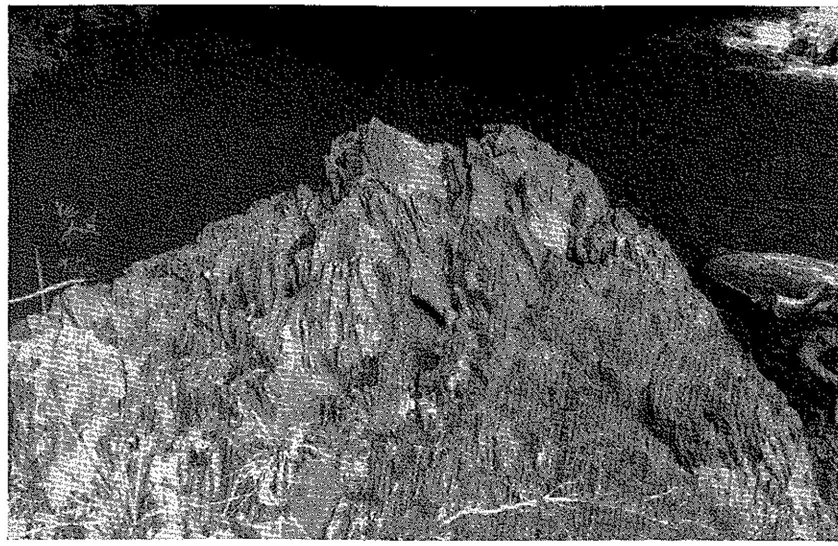
The Gran Chaco, between the Andes and the Chiquitano system, has Bolivia's oil possibilities. This area has been receiving deposition almost continuously since Cambrian times, i.e.; it has been a negative crustal area. The Chaco Boreal is a structural shelf of the Andes. It is a mass of sediments gently folded into large structures, with more abrupt folds at contact with the "Vorland." The eastern edge of the Chaco is more than 200 kilometers west of Brazil. On the other side, west of the Sistema Chiquitano, the Cordillera de Sunsas is composed of granite and gneiss, easily studied. The geological separation, then, is 200 kilometers into Bolivia.

PART II

Geology

The region studied is considered as a crystalline shield occupying the central section of South America, to which is given the name "Paraguaya." This shield separates two sedimentary basins, the East and the West, comprising sediments from the Devonian to the upper Tertiary, with many gaps. In the East, i.e. the Paraná Basin, the sedimentation took place in

▼ Fig. 4—Typical vegetation on the sandy soil of the Botucatu formation.



▼ Fig. 5—Shales in the Santo Amaro River near the contact of Botucatu sandstones at Fazenda (farm) Santo Amaro.

a shallow basin, resulting in sediments of less than 5,000 feet thickness. In the West, however, i.e. the Chaco proper (Chaco latu sensu) and the Sub-andine shelf (Faja Sub-andina), the same geological deposits have four to five times this thickness, or up to 25,000 feet. The correlation of local stratigraphic standards is given in table I.

The "Paraguaya" shield always has been a source of the deposits which today fill both basins. On the Brazilian side, however, in Rhaetian times, there was a great outpouring of basalt which overflowed, in the opinion of the writers, as a result of isostatic balancing. The great outpouring of Brazilian lava is comparable with those of Oregon (U. S. A.) or of Dekkan (India). The surface of this basalt constitutes an immense trap of at least 600 feet thickness, covering a large part of the Central Plateau of Brazil. Because of this, from Rhaetian times, the erosion in Matto Grosso has had a tendency to continue on the crystalline shield, wearing it away to the present altitude of 300 to 900 feet, while the basaltic topography remains at an altitude of 1,800 feet, at the top of the "Serra de Maracaju," which is the western border of the above mentioned trap. This fact helped the tributaries of the Paraguay River to wear not only the granitic core rocks, easily decomposed by weathering, but also the soft sands of the "Chaco," as the erosion process, in this case, essentially depends upon the base level which is the same for both, i.e., the mouth of the Paraguay River (River Plate) in the Atlantic Ocean. Some rocks, being very hard, remain as buttes as in the case of the above-mentioned formation (Bodoquena) and the district of Macisso do Urucum, and contain iron and manganese ores.

In the crystalline peneplain of Matto Grosso (the Pantanal), the overflows of the rivers, during the floods, are always very extensive and the river beds join one another, forming one vast expanse of water about six feet deep. This forms a hydraulic system of compensation which is always present in the Matto Grosso rivers. As a result of this special feature in this region, it is called "Pantanal" (swamp), although in reality the ground is firm and not swampy. On the other hand, in the "Chaco," the run-off is very low because the porosity of the sand is very high, and most of the drainage of rain water is as underground water (although this is relatively small, because the evaporation rate is high in the region).

Curiously enough, the word "Chaco" is written in Portuguese almost in the same way as a synonym of "Pantanal," the word indicating the above-mentioned natural feature. We refer to the Portuguese word "charco" (swamp), (pronounced shah-ko). Perhaps this resemblance of words helped in making people think of Pantanal (charco) as a continuation of "Chaco." As previously mentioned, the Brazilian Government's Group went to Bolivia, where they studied the territory and also the library composed of the confiscated reports of the Standard Oil of Bolivia. A result of this study was the not yet published, "Rasgos Generales y Posibilidades Petroliferas de la Faja Sub-andina de Bolivia," por Glycon de Paiva, Guillermo Mariaca e Jorge Muñoz Reyes (General Rules and oil possibilities of the Sub-andine Shelf in Bolivia).

In the west, in Bolivia there are two important divisions: The Andine (mountainous) and The Paraguayan-Amazonian (lower drainage basins of these rivers in Bolivia). The former is about 2,000 to 7,000 meters in elevation, the latter from 100 to 500 meters in elevation. This explains the political-diplomatic difficulties of Bolivia.

The "Faixa (shelf) Sub-Andina" of 50 to 100 kilometers in width from the Argentine border north to Santa Cruz, thence north westerly to Peru, is also the petroleum shelf of Bolivia; it has dozens of seeps, some of which, as at Espejos, not far from Santa Cruz, are commercially productive (Plate I and III). A part of the Andine Shelf is the lower shelf, marked by a series of small mountains up to 1,500 to 2,000 meters in elevation, separated by low plains like inter-mountain bays. If the oil indications of the Bolivian Andes have little importance, neither do these in Paraguayan-Amazonic Bolivia, as just defined. Oil is found only in the Sub-andine shelf running parallel to the Matto Grosso frontier at 650 kilometers distance to the west. The Amazon basin in Bolivia (called "Beni") is a level jungle-covered plain, with no notable mountains. Actually, we repeat, the "Chaco Boreal" as defined has no known oil. We do not know of any geological study of this region, it is merely a broad dry plain, with no structural indications, marked only by Bolivian forts. The only geological work studied relative to the "Chaco Boreal" was that of Dr. A. Topia, of the Argentine Geological Service, on the Argentine margin of the Pilcomaio river. It did not mention oil. The Bolivian post-war literature has numerous and stirring descriptions of the dryness of the region. More died of thirst than from bullets in the War of the Chaco. The Gran Chaco is a municipality of the State of Torija and is well populated. It lies along the Sub-andine Shelf, to the extreme south of the oil shelf. It was not the theater of war, even though the Paraguayans came almost within artillery range of the nearest oil well. In the last treaty, the Gran Chaco oil became permanently Bolivian. The territorial sacrifices by the Bolivians were in the Chaco Boreal or "Vorland," where oil has not been found. The Gran Chaco is a mountainous shelf of the Andes, structurally it is a "Vorgebirge." It is the opinion of some that the contact of the Vorland with the Vorgebirge may be an oil trap. The Spanish term "Chaco" is the equivalent of the Portuguese "roca," which means cut jungle, burned to clear the land, then planted.

▼ Plate IV—Geological structure of South America. Translations of legend: "Fundamento Sob Sedimentos continuos"—Depression with continuous sediments. "Bordo da Cordilheira"—border of cordillera. "PS Regiao das serras pampeanas"—Region of the Pampa Range.

It is *the opposite* of a flooded territory.

Notes on the Gondwana of southwest Matto Grosso

In order to locate the east limit of the formations of the Paraguayan lowlands, which are presumed to be potentially oil-producing, a study of the Gondwana Plateau of Southern Brazil (which extends to Matto Grosso and terminates in an erosion scarp similar to the Botucatu scarp) was made. The Botucatu (Maracaju) sandstone (Fig. 5) and lava flows, nearly 400 meters thick, mask the Ponta Grossa and Iraty formations. These must be studied before the area can be proven. Some important differences in decomposition products of basalt were observed, i.e. an unproductive "terra roxa" which means this subject warrants considerable study, since "terra roxa" is the rich soil which yields Brazil's coffee and cotton.

Geologic Relations of Parana Basin and Sub-andine Region

"It is necessary clearly to distinguish and separate statements of facts from sound inference and legitimate speculation."—Nevin, "Principles of Structural Geology." The chapter containing this material has fascinating and very logical inference and speculation, based on the mass of data presented in preceding chapters. In his discussion of the Gondwana, Gerth, page 2, volume 1, "Die geologischen. Strukturelementa Sudamerikas," considers that there are three shields in western South America—Guiana, Brasilia, and Patagonia, (Plate 4). He related the "Serra Pampeanas" (Pampa Ranges) of Argentina to the Brasilian shield. In the language of Suess-Wegener, "Are these three nuclei independent masses of Sial, floating on a common Sima, each capable of small epeirogenic movements, or proper 'tilting,' or do they compose a single block of Sial, including all of western South America?" In either case, they are of sufficient extension to merit three names. Gerth includes the Upper basin of the Paraguay, Taquarí, and Sao Lourenco, in the Algonquian uplift, thus signifying that the shield is composed principally of rocks of this age. In reality, that is what occurs in Matto Grosso. This concept, which must be considered in the relations of the crystalline nucleus of Matto Grosso and the Paraguayan shield, must be clearly held in mind, for the two last mentioned, if not one continuous mass, must then receive separate designations, and the latter must be called "Paraguaya." An alternative, according to Gerth, is to consider the Pampa Ranges as part of the Brazilian Shield. (Translated from German) "According to recent studies the southern parts of the old Brazilian nuclei have sunk, thus creating the space for the deposition of extremely thick sediments of the Argentine Pampa whence the ancient rocks protrude as monadnocks, composing the Pampa ranges." Nevertheless, the high scarps attained in the last geological times by Brazilia, in the Coast Range, in Sao Paulo, faults of 1,500 meters vertical displacement, are not found counter-balanced in Matto Grosso, where the crystalline is represented by a low peneplain of 100 to 200 meters altitude, which may indicate the relative independence of B r a z i l i a and Paraguaia. This would simplify the explanation of the relationships here, as we shall see. A geologic-physiographic fact most marked in the region is the difference of two or three hundreds of meters between the surface of the crystalline nucleus and the sub-basaltic surface of the sandstones of Maracaju. The crystalline surface is the source of sediments for the lower surface, which reverses the conditions in Sao Paulo State. The Maracaju surface, since Rhaetian (upper triassic) times, has been protected from erosion by the 200 meters thickness of basalt; glyptogenesis (rock erosion) meanwhile proceeded freely in the crystalline surface, which was unprotected except for some thin flows. The difference of elevation existed from Rhaetian to the present. The principle of isostatic equilibrium between independent nuclei of Sial (essentially aluminum silicates) is generally admitted, hence, where there is erosion, there is emersion of the eroded tract, which is progressively lightened, thus, to erode 1,000 meters of surface requires the emersion of a continental mass on which glyptogenesis had removed 900 meters. The measurable difference of elevation would be scarcely 100 meters or 10% of the actual erosion. The 900 meters of space created by the progressive displacement which took place is gradually filled by the compensatory mass of Sima, (viscous basalt essentially magnesian silicates) in accordance with the laws of isostasy. We understand isostasy not as a force but as a necessary consequence of gravity and rotation; a tendency always present for the reestablishment of equilibrium, operating under, though sometimes on, the surface of a magma, the latter occurring if there are crevices with large vertical projection in the Sial.

During the emersion of a block of Sial such as the "Paraguaia," there must be either increase of the mass of the block by accumulation of basalt, or increase in volume without alteration of the mass. The increase of basalt, although principally in the lower part of the block of Sial, may have taken place in any part of a continental block, particularly on the surface, if this had communication with the reservoir of Sima. This is the origin which must be suggested for the immense basaltic trap of Southern Brazil, in the hypothesis which admits of an independent block for Paraguaia. Conversely, a chain of archean mountains, formerly occupying the region just studied, would well explain the reason for homologous sediments in the Paraná basin and the Chaco since the eodevonian; permitting, on each side of Matto Grosso, the identical sedimentary series, although those in Bolivia were four or five times as thick as those in Brazil. Apparently the sedimentation in Bolivia was principally in a geosyncline while in Brazil it was in an area scarcely equicontinental. One may also suppose that a block of Sial, exposed in Matto Grosso, is the source of the sediments of the Paraná Basin and the Sub-andine region. Judging by actual thicknesses of geologic columns, only one-fifth was deposited to the east and the balance was deposited to the west. Since the material was derived by natural erosion of the Matto Grosso shield along then existing drainage patterns, the area must have had a generally westerly slope. The effusion of basalt which must have occurred as a counter-balance for isostatic increase of mass, would have had a tendency to accentuate this inclination towards the west. The lack of basalt in the sub-andine region would be an argument in favor of this. We do not deny that these opinions may be expressed in terms beyond the comprehension of the layman, and that the consideration of forces seen in the relatively small masses with which we usually work, weakens our arguments for such large scale speculation—but a well known tendency of the human spirit is to try to support a theory, imperfect though it may be, from which, by deduction and new inferences we may, perhaps, comprehend the unknown.

Table 1 shows the parallelism of formations on each side of the positive nucleus of Matto Grosso. Considering the table, we notice in the sub-andine column a lack of pyrobituminous Iraty-shales, which indicates an important difference in exposures from one side to the other of Matto Grosso, during the epoch of deposition of this shale. Thus the Paraguaia was an island in the devonian sea of South America, and probably one of the multiple centers of permocarboniferous glaciation in South America. Other differences in the two geologic columns are: Nearly all the glacial conglomerates which are seen in Bolivia are drift conglomerates, not true tillites as those in Brazil. In other words, Brazilian glaciation was more terrestrial than that of Bolivia. Also noticeable in Matto Grosso is the transgressive

▼ Fig. 2—Branding calves—Matto Grosso.

character of the Botucatu above other masses of permo-triassic formations. On the Matto Grosso edge there are only two exposures of devonian formation known, these are Santa Ana da Chapada, in Brazil, and Orroyos, in Paraguay. Probably a trip along the Paraná river would enable one to study successively all the lithologic members which compose the stratigraphic column of White (1908). It is interesting to note in the table of Bonarelli, a reference to what may be Bauru; while in the other tables the upper basaltic series, which is lacking in Bolivia, is present in Missoes, Argentina. The topography of this region, particularly the lack of easy passage between the Paraguay river and the scarp of Maracaju, hindered the Spanish incursion along the edges of the central Paraná.

PART III

The Inhabitants and Their Mode of Life

The ox is an essential beast of burden in this "pantanal," (Fig. 1). Cattle were introduced by Missionaries (Jesuits) from Guaira and by Sr. Mojas from Goias in 1730. In 1900 the Zebu (Brahma) of Uberaba was introduced, which is replacing the Caracu (long-horn), and the Zebus now probably number one million, or ¼ of the cattle in all Matto Grosso (Fig. 2). The main obstacle in the way of development is the lack of efficient river transportation from Corumbá to Buenos Aires. The government, by ensuring this, can make development of the area immediately possible. Cattle, fish, minerals, ornamental building stones, fruits, woods, all are available. The "Lloyd Brasileiro" and "Milanovich" are the present unsatisfactory river transports. The Paraguayan basin in Bolivia is covered with sparse bush, resembling at times the northwestern bush; it is also lacking in exposures, and no exception is the "Chiquitano system," stretching half-way between Santa Cruz-Corumbá, between the towns of S. Jose de Chiquitos and S. Ana Emquanto, below 150 meters altitude. The Paraguayan basin in Bolivia comprises several states (Tarija, Chuquisaca, and Santa Cruz). The "Chaco Boreal" is a territory (like Acre in Brazil), and is considered a part of Tarija. The Bolivians designate this as "The Triangle," lying south of parallel 21, west of the Rio

TABLE 1

STRATIGRAPHIC STANDARDS ON EAST AND WEST SIDES OF PARAGUAYAN SHIELD

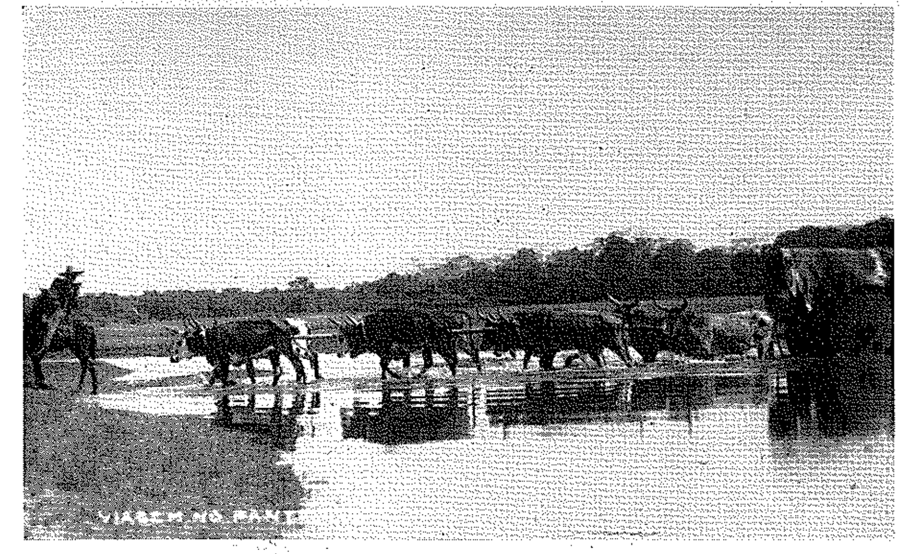
Bulletin 37 (1)

Ages	*Brazilian Standard White, 1908*	*Bolivian Standard YPFB, 1937*	*Argentine Standard Schlagintweit, 1937*
Cretaceous	Bauru	Dolomitic Ls. Level	Dolomitic Ls. Level (Xs-Xi)
Rhaetian	S. Bento Series	Lower Massive ss	Lower ss. (y)
Triassic	Passa Dois Series	—	—
Permo-Carbon.	Itarare Series	ss and Tillite or Gondwana beds	Paleozoic Beds
Devonian	Parana Series	Micaceous shales	

TABLE 2

STRATIGRAPHIC STANDARDS OF EAST AND WEST SIDES OF THE CRYSTALLINE SHIELD OF MATTO GROSSO

Brazil—East	*Bolivia—West*	*Argentina West & South*
White—1908	Y.P.F.B. 1937	Schlagintweit—1937
Tertiary of interior of S. Paulo and Matto Grosso	Sub-andine Tertiary	(T) Camada Jujenhas (Tc and Ti) Tertiary Sub-andino
	Massive upper sandstones	(U) Upper ss. of Jujuy (V, Mc, and Wi) Multi-colored marble
Bauru sandstone	Calcareous-dolomitic horizon	(Xs and Xi) Calcareous-Dolomitic. Cretaceous Horizon
Sao Bento series	Massive lower sandstone	(y) Lower sandstones
Passa Dois Series	—	—
Itarare-Tuberao	Sandstone with Gondwana Tillite	Paleozoic
Devonian of Parana	Micaceous shales	



▼ Fig. 1—Travel by oxcart thru the interior of the Pantanal.

Paraguay, and north of the Rio Pilcomaio. It was little inhabited by Bolivians, but was settled by Paraguayans who had easy access to it across the Paraguay river (Fig. 3). This was the scene of the "War of the Chaco" in 1932, started by Pora, attacking the Bolivian forts of Nanama and Boquerin, 250 kilometers from Assuncion, a few kilometers east of the first oil well of the Gran Chaco on the Sub-andine shelf. Thus all the right bank of the Paraguay is under Paraguayan influence. Auto roads have deep ruts, but the area can be safely crossed by model "A" Fords. Corumbá and Porto Murtinho are subject to annual floods. The fazendas (ranches) are enormous, from 30,000 to 500,000 hectares in area.

On these properties, a closed economy exists. The people buy salt, ammunition, kerosene, clothing, little else. Maté (Yerva Maté, a nutritive, vitamin-rich tea) and beef are the principal foods. There is practically no money in circulation, so an essentially feudal system prevails. There is no real society. After a few days visit, to the outsider, living on the fazendas is intolerable because of the monotony of the diet, since no green vegetables or variation from "roast beef and maté" are known.

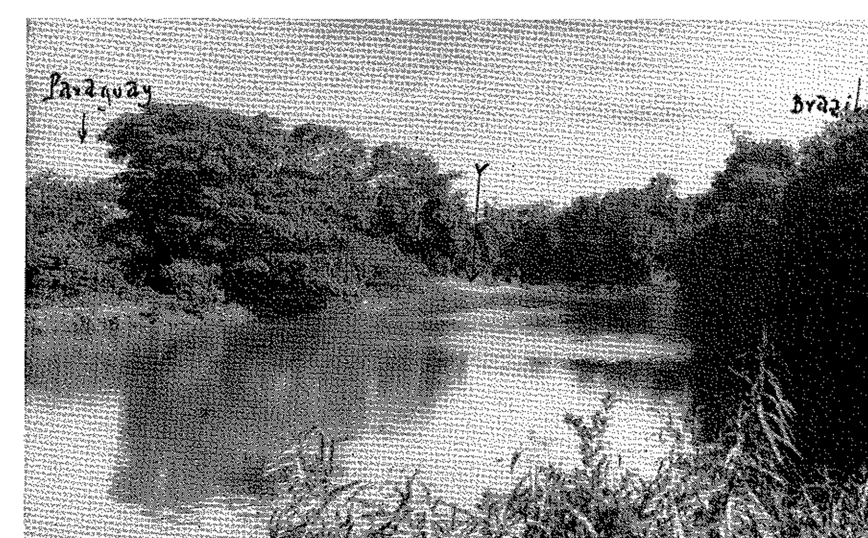
A typical fazenda has a "casa" (residence) for the landlord and a "galpao" (bunk house). The visitor to the fazenda must stay in a "galpao," where the "peonada" or cowboys live with all their equipment. The nights are always uncomfortable here, with conversation of the peons, who sleep in hammocks slung one above another, baying of hounds, and countless myriads of hungry mosquitoes. The number of mosquitoes in the Pantanal can be gauged by the fact that in the long train ride from Carandazal to Porto Esperanca, travelers close all doors and windows (even on the dining car, in spite of the heat from the kitchen). They also cover their heads with towels.

In the Pantanal of Matto Grosso there is a general distrust of all travelers. In all this 80,000 square kilometers live barely 20,000 people, without police, law, schools, or doctors. There are two classes, the agregados (agriculturists) and the peonada (cowboys), the latter usually Paraguayan or Argentinian. Usually the employers learn the language of their employees to the detriment of Portuguese. The languages, in order of use, are, Guaraní, (Indian), Spanish, and Portuguese. The army maintains troops in Aquiduana, Bela Vista, and Porto Murtinho. These are necessary to insure a traveler safe conduct on *any* trip. The entrance of troops into this territory improved the general public's safety. It is an historical fact that the early inhabitants were Aruak Indians and were called "chacos," and they lived in the actual "Chaco Boreal."

Missionaries have been working here. In this country of poor people with only elementary ideas of comfort, food deficient in quality and variety, and a low scale of life, we find the Latin Catholic priests, Padres Redemptores (Order of S. Geraldo Majela). The exact contrary of this poor scale of living is seen with the priests; in fact, no one lives better in Matto Grosso than the "Padres." These "patrons of living," largely deriving recognition and reward from the number of converts which they make among the inhabitants, have the highest education, among people who decidedly do not know how to live! The benefits they bring to these people are countless! American Missionaries have begun to build in this region beautiful "Casas dos Padres" (mansions of the priests) where all modern comforts are installed. These houses have lines of singular beauty (Dr. Camilio Boni, an Italian architect who lived here years before, designed them). Here are taught the Portuguese and sometimes the Guaraní languages. The priests also travel by auto, performing marriages, baptisms, and dispensing generally spiritual and material favors, asking nothing of their public. All this was done in true American style—decidedly, generously, by tireless priests. Concerning these aggressive missionaries all sorts of gossip was made: they were American emissaries to get oil, they were spies, etc., in fact, all that the fertile, sick, untrained mind of the Brazilian cowboy could imagine. But the evidence forces us to admit that the padres are as great an aid

(Continued on page 460)

▼ Fig. 3—The Paraguay River, between Paraguay and Brazil.



SOMASTIC PIPE COATING

For Permanent Protection of Underground Pipe Lines

By
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Research studies and field investigations concerned with steel-pipe corrosion and its mitigation show the existence of several coating materials having the necessary physical properties to supply protection consistent with economic requirements. In the past, however, difficulties have arisen in the application of these materials to the pipe, with the result that the pipe line operator has not always been assured proper protection of his line.

The remarkable efficacy of thick asphalt-mastic coating in particular has been noted by investigators. Recent developments in the application of this dense material to the pipe indicate that equipment currently in use is adequate for this work. As now applied, the SOMASTIC COATING withstands handling during pipe line construction, and in place furnishes the ultimate desired protection to the operating line. The improved technique of application is reviewed in the following summary of current methods employed with asphalt-mastic coatings.

Preparation of Pipe

In order to secure the maximum bond of coating to pipe, the proper preparation of the pipe is necessary. All pipe is thoroughly cleaned by shotblasting with steel grit if the operation occurs at a central plant or railhead plant, or by sandblasting if the coating operation is to take place "over-the-trench." Shotblasting is accomplished by means of a rotoblast machine wherein steel grit or shot are fed into the center of a wheel rotating at high speed and thrown from the circumference of the wheel against the outer surface of the pipe. This action not only cleans the pipe, but also roughens the surface so a more intimate bond of primer to pipe can be secured. The operation is economical, in that blasting material is trapped and rerun through the machine several times. Although the preliminary design has been prepared for equipment to rotoblast lines in place in the field, this equipment has not been perfected to date, and operating lines are cleaned by the orthodox sandblasting method.

Immediately after shotblasting, pipe is heated to a point varying from 110 to 160 degrees, depending upon operating temperatures and humidity, and hot primer is applied to the pipe. Six-tenths to nine-tenths of a gallon of primer is used to one hundred square feet of pipe surface.

Selection of Materials

All materials are carefully selected to conform rigidly to the following general specifications:

Air blown asphalt from selected crudes; 21 to 25 penetration for regular cold line service, and 15 to 17 penetration for hot line service.

Non-micaceous washed sands; carefully graded, all passing Tyler Standard No. 6 Screen, and graded to conform to specific maximum density curve.

Commercial limestone dust; free from dirt or foreign matter, 100% passing 50 mesh and 75% passing 200 mesh.

Long willowed asbestos fiber; free from dirt, grit and moisture.

All materials are checked daily and weekly samples run to insure the use of proper materials at all times.

Manufacture of Mastic

Based upon the analysis of local available sands, the correct proportion for the mix is established by determining the proper proportion of lime-dust fines to be added to the aggregate. The general proportions of material in the mastic mix are as follows:

Asphalt	12% by weight
Asbestos	1% by weight
Sand	63% by weight
Limedust	24% by weight

The materials are blended and mixed in a specially built asphalt-mastic heating plant designed to maintain absolute control on proportions and temperatures of the mix. Two pug mills are used so that a continuous flow of mastic can be delivered from the machine, sufficient mixing time being allotted to each batch in order to secure a density of 135 lbs. per cu. ft. After mixing, the mastic is delivered by heated screw conveyors to the coating nozzle.

Application of Somastic

The dense mastic is extruded simultaneously over the circumference of the pipe in a continuous process by means of a new asphalt-mastic nozzle which assures the application of a seamless coating. The hot mastic in a semi-plastic state is pumped into the nozzle encircling the pipe. This nozzle is uniformly heated, and constructed to form an annular aperture of fixed radial size with a taper on the outgoing end of the nozzle. Pipe is driven through the nozzle, or as an alternate process the nozzle is driven along the pipe, and a compact coating of mastic is extruded onto the pipe with a resulting thickness of coating of one half inch on 8" pipe. This thickness can be varied to comply with the desired thickness required for the particular size of pipe being coated.

Thickness & Weight of Asphalt Mastic Coating

Standard Pipe	*Nominal Coating Thickness*	*Estimated Wt./Ft. Lbs.*
1"	5/16"	1.49
2"	5/16"	2.50
3"	3/8"	4.28
4"	3/8"	5.38
6"	7/16"	9.10
8"	1/2"	13.45
10"	1/2"	16.56
12"	1/2"	19.51
14" OD	1/2"	21.35
16" OD	9/16"	27.50
18" OD	5/8"	34.25
20" OD	5/8"	37.96

NOTE: To offset the buoyancy of natural gas lines laid in marsh and water, the thickness of coating can be increased. For example, 12 3/4 OD gas line could be coated with 5/8" thickness giving a weight per foot of coating of 24 lbs.

Types of Plants

Several types of plants are available to make the proper application to new and operating pipe lines under various conditions.

The central plant is designed to handle the coating requirements in an area warranting the maintenance of permanent coating facilities.

The railhead plant consists of semi-portable equipment that can be moved to the site of the line to be coated.

The small-diameter plant is designed to handle the requirements of gas distribution systems using small diameter pipe.

Over-the-trench equipment is used for the purpose of reconditioning and applying asphalt-mastic to existing lines that cannot be taken

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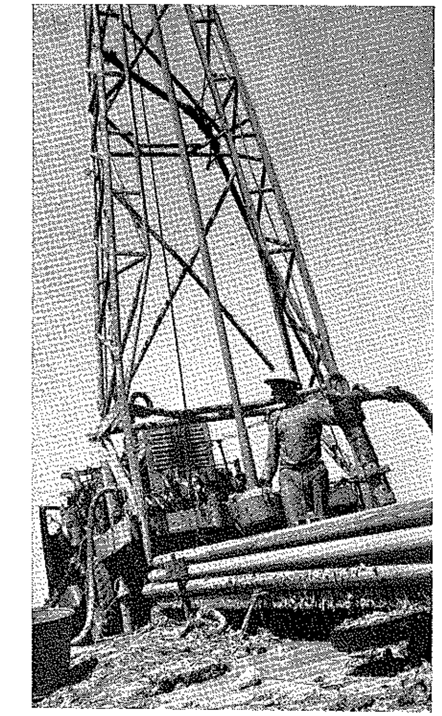
REQUIREMENTS OF A MODERN SEISMOGRAPH SERVICE



▼ Deep Shot Hole Drilling.

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The success of the reflection seismograph in mapping oil bearing structures and its ability to obtain accurate and pertinent subsurface information not obtained by other geophysical methods has been well demonstrated. Current success and past discoveries credited to geophysical exploration are responsible for the extensive use of seismic parties at the present time. It is estimated, that two hundred or more parties are in operation in North and South America.

The methods used by all seismograph parties are basically similar, namely the photographic recording of ground motion generated by a subsurface explosion. However, parties vary in the quality of their equipment, in their ability to obtain data, their ability to effectively treat the data, and their efficiency of operation. Any client operator who contemplates using the services of a reflection seismograph party will wish to investigate these points carefully.

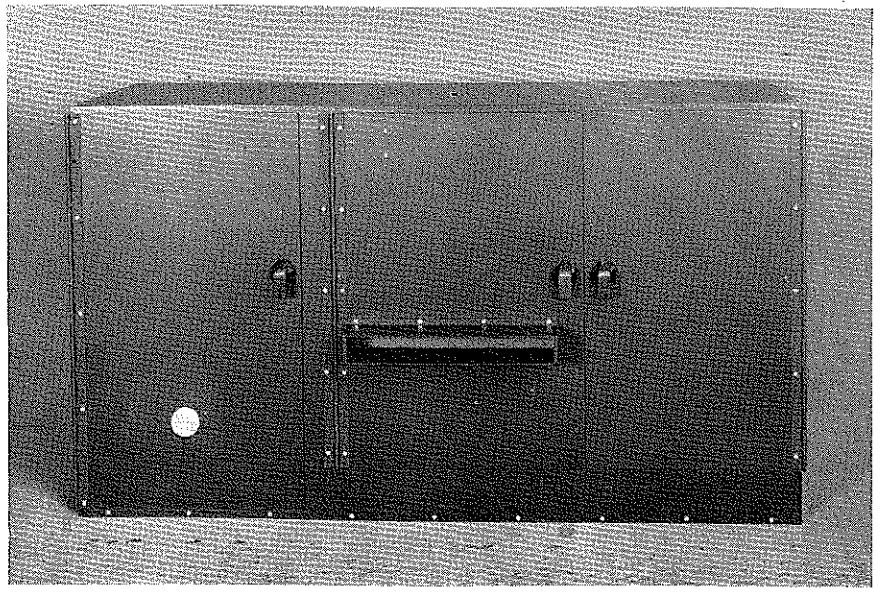
In this regard it is well to remember that the easily mapped seismograph prospects in favorable parts of the country have been investigated and are no longer available. Therefore, future reflection work to be successful will require the best equipment available combined with a highly developed technique. In general, future success of seismograph work will be proportional to the degree of refinement of equipment and technique.

Recording Unit

In these considerations the recording unit is of prime importance, because without properly designed and constructed equipment no party can deliver complete and trustworthy information. Particular attention must be given to the required fidelity with which the ground motion is recorded. Every recording system inherently introduces some distortion. First, certain frequencies are transmitted or amplified more than others. Second, the phase of vibrations is shifted, resulting in a time lag, different for different frequencies, between the motion of the ground and the motion of the light spot or shadow on the photographic paper. Third, the transient response, that is, the response to a sudden ground displacement, is more complicated than the actual ground motion. It is desirable to have this response as simple as possible in all parts of the recording system. Quite obviously the accuracy of results obtained may be seriously impaired if these factors are not carefully considered in design and construction.

Seismometers

The receptors or seismometers used by various companies are of many types. However, every seismometer system should have constant or nearly constant characteristics independent of time or the ordinary temperature variation experienced in the field. Also considerable care and research should be devoted to secure desirable frequency characteristics, minimum phase shifts, and simple over all transient response. One of these problems has been solved by using electromagnetic damping in the seismometers and oscillograph. Electromagnetic damping of a variable reluctance type seismometer has been attained without lowering the natural frequency of the instruments. It is accordingly possible to use the low frequency cut-off characteristics to eliminate undesirable low frequency "ground roll" present in seismic work. Electromagnetically damped seismometers with low natural frequencies have been used at various times, but with the disadvantage of requiring the use of additional filters to remove low frequency components. Since it is much more difficult to obtain electromagnetic damping with higher mechanical natural frequencies, most seismometers of the not distant past used oil damping. The fundamental difficulties and disadvantages of oil damping arise from the wide variations of oil viscosity with changing temperatures. During the cool morning hours the oil may be thick and viscous, resulting in sluggish instrument response, while at high temperatures later in the day the oil may become thin and the instrument resonant at its natural frequency. The frequency characteristics of the recording system will consequently be continually changing. Frequent substitution of oils of different viscosities will partly, but not completely remedy this very unsatisfactory condition. With electromagnetic damping on the other hand, the damping and frequency response characteristics remain essentially constant. This constancy is essential if records are to be accurately compared and correlated. In addition to being electromagnetically damped, seismometers should preferably have large outputs so as to require only a moderate amount of electrical amplification. Seismometers which require large gain amplifiers introduce a difficulty which makes them in general unsatisfactory for field use.



▾ Complete Recording Camera, Illustrating 24 Trace Observation Screen on Center Door.

Amplifiers

The difficulties associated with the use of high amplification, for example, microphonic tube and input transformer noises, "motorboating," "feed back," "cross talk," and other undesirable features are avoided when low gain amplifiers are used. Amplifiers used for seismograph work should have a uniform response and minimum phase shifts over the range of important frequencies.

Amplitude Control

The photographic recording of amplifier outputs in seismograph prospecting presents a problem because of the wide range of amplitudes generated in the ground by the detonation of explosives. If the amplifier gain is kept constant during a recording, the seismogram is unusable in its earlier portions because of the large amplitudes. It is possible to shoot a number of charges of dynamite, each successively larger, and then by piecing together data from the usable parts of each record, obtain more or less complete information. Such a procedure is obviously inefficient, wasteful of time and explosives, and involves a considerable risk of losing the shot hole before all records are taken. An improvement adopted by many operators is the use of a relay or manually operated gain control which suddenly increases the amplifier gain when amplitudes fall below a chosen value. This method, however does not give completely satisfactory control of record amplitudes, and usually introduces a large extraneous transient at the time of change in gain, rendering the record unusable for the short time interval.

Automatic Gain Expander

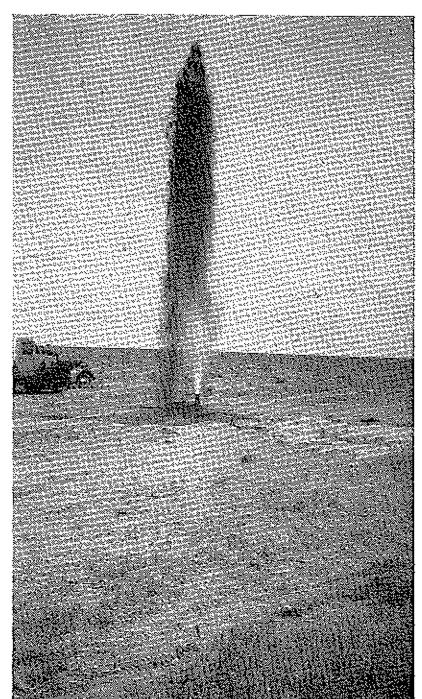
Many operators have accordingly incorporated in their equipment automatic or semi-automatic amplifier gain expander systems, which result in a usable record for the entire length of the seismogram. Early reflections from a depth of a few hundred feet can be recorded as easily as late reflections from depths ranging from 1 to 25 thousand feet. At the instant of the explosion, when the amplitude of the ground motion is large, the gain of the amplifiers is made correspondingly low, so that normal amplitudes are recorded on the seismogram. As the amplitude of ground motion decreases, the gain of the amplifiers is automatically expanded at such a rate that the seismogram amplitudes remain within desirable limits. Furthermore, the control is smooth and continuous, introducing no abrupt changes of amplitude. Automatic gain control systems reduce considerably the number of shots required per shot hole, greatly facilitates the computing of results, and makes possible the most economical use of time, explosives, and shot holes.

Galvanometers

The same fundamental difficulties which apply to the use of oil damping in seismometers are present in the case of galvanometers. It is desirable that the galvanometers should be designed with electromagnetic damping and a natural frequency high enough to insure uniform response up to approximately one hundred cycles per second. Above this frequency the response may fall off gradually, resulting in a filtering out of undesirable high frequency "wind noises" and other disturbances. Such instruments must be ruggedly constructed, with high sensitivity and frequency characteristics independent of time or temperature.

Number of Recording Channels

The use of twelve or more recording channels rather than a smaller number is in agreement with modern construction practices. Recently extremely portable equipment has been constructed using twelve independent channels. Each package unit of this new equipment weighs not more than fifty pounds, and consists of only six packages. Other factors being equal, the amount of data obtained per dynamite explosion is proportional to the number of recording channels employed. In particular a twenty channel seismograph outfit can, with one set-up and one detonation, record an amount of data requiring two instrument set-ups and two explosions with a ten channel outfit. The data obtained are more desirable because they are all on the same record with a common set of timing lines, allowing a rapid and accurate examination. The identification and computing of reflections is fundamentally a process of correlating the motion of the ground at a number of points, and accurately comparing for each point the time elapsed since the instant of explosion. Even under most favorable and apparently identical shot hole conditions, ground motion may not duplicate itself exactly for successive dynamite explosions. Since time comparisons must be accurate to within 0.001 of a second, the advantage of obtaining information for a maximum number of points per shot is clearly evident. In addition, the use of a large number of traces greatly facilitates shooting practices, lessens the danger of losing shot



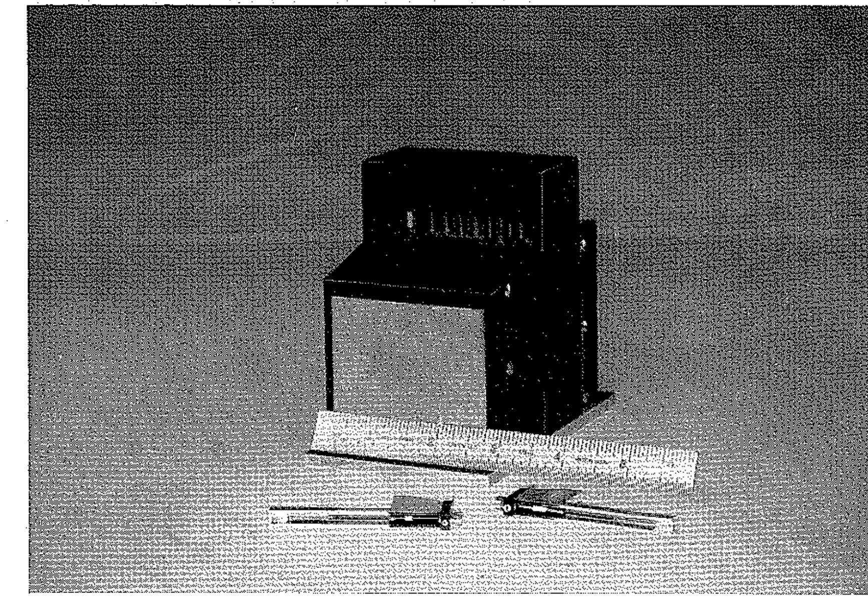
▾ Deep Shot Hole Blow.

holes before all data are taken, and reduces the amount of time and explosives required per shot hole station. It is often possible to record simultaneously two reflection components at right angles when a large number of traces are available.

Recording Systems

When a charge of dynamite is detonated, the motion of the ground arises not only from energy arriving by direct and reflected paths, but in considerable part from complicated trains of secondary waves. These waves are generated because of the heterogeneous structure of the ground, in accordance with the intricate mechanics of elastic wave propagation. If the amplitude of a reflected wave is comparable to, or smaller than, the amplitude of the complicated "background" motion, it is difficult or impossible to recognize the motion as a reflection. Any scheme which tends to make the reflection phases stand out more clearly from the "background" of the record is a valuable aid in computing and interpreting data. Several methods have been devised including the use of "multiple seismometer systems," that is, the use of several seismometers in various combinations in each recording channel. A number of circuit networks have been developed for recording which result in a distinctly more favorable ratio of the amplitude of reflections to that of the "background." In routine field procedure one or more records are taken with the several different circuit networks.

A system which has received some attention recently in areas where reflections are difficult to obtain is a combination of multiple seismometers and a twofold recording arrangement. The twofold recording arrangement consists of the normal recording apparatus plus a magnetic tape recording device or some other recording method that will make a record that can be immediately played back. By the use of this equipment two records are made simultaneously employing automatic amplitude control. The conventional seismogram is recorded by means of the galvanometer system and a second record is for example made on a magnetic tape. The magnetic tape used is wide enough to accommodate all of the traces in such a manner that each channel can be played back through the recording head in exactly the same relation as when recorded. The first record is removed from the conventional recording camera and developed. The record on the tape is then played back through various circuit networks to the regular recording galvanometers and conventional records are made. Several circuit networks are usually available for this playback recording making possible



▾ Ten Element Set of Galvanometers Used in Portable Equipment, Illustrating Galvanometer Design.

the recording of the ground motion by various responses to the original ground motion. When the desired number of photographic variations in recording are obtained the magnetic tape is cleared of its record and thus made ready for the next recording.

The practice of making the playback recording with a much higher fidelity to the ground motion than that of the ordinary photographic record seems to justify the re-recording from the tape by several different circuits. It is thought that this system makes possible a better analysis of the ground motion without increasing the amount of explosives used or expense of drilling extra holes. Unfortunately the principle of making seismograph recordings which can be played back or reproduced in second recording is covered by broad patents. The patent obstacle in making of reproducible records has been overcome to some extent by using several sets of galvanometers making several records simultaneously in the conventional manner of making photographic seismograms. This arrangement has the disadvantage that several optical and recording systems are necessary which increases the amount of complicated and expensive equipment.

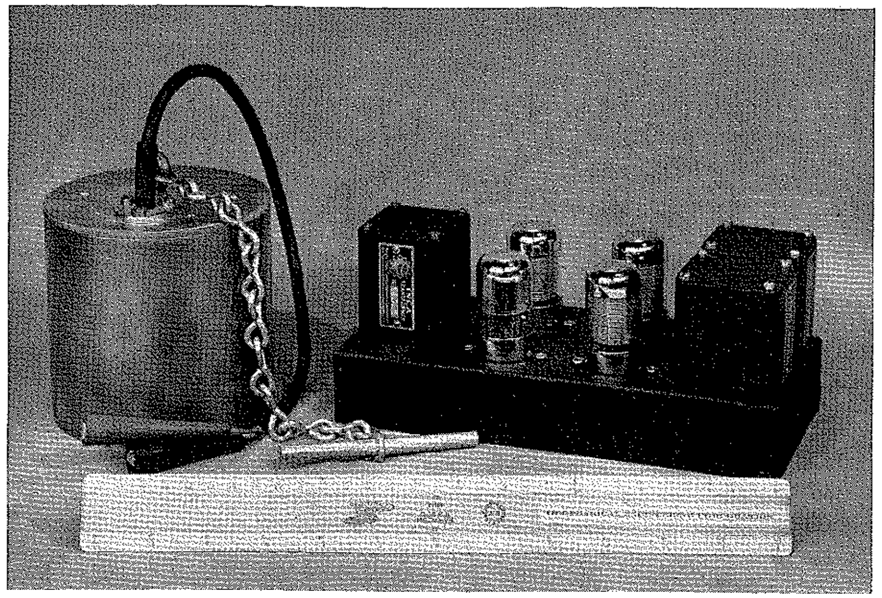
The so-called overlap of traces and various methods of coupling of adjacent traces should be used with extreme care because of the following:

1. The excessive mixing or overlap of traces will produce records which exhibit some reflections which may not exist.
2. Various amounts of overlap or mixing of the recording channels vary the effective length of the instrument spread.
3. Strong recording of a few traces in a group will generally distort the apparent reflected wave front of the other weak traces of the group.
4. By excessive mixing of channels the time difference between phases of the traces may be controlled by disturbances on one or more of the traces in the case of reflections of low amplitude.

In using these types of circuits for recording it is advisable to record a suite of seismograms in order to clearly demonstrate by steps the effect of the reduction of the so-called background amplitude in comparison with the amplitude of the reflections. In all cases it is desirable to have one good record representing independent channels at each station. This is one of the advantages of the twofold recording system as this type of record is the first seismogram made. A criticism of coupling the recording channels to improve the record appearance is that if too much coupling is allowed synthetic reflections may appear on the records.

Too many of the so-called improvements in equipment, under the stress of competition, are various methods of cross feeding between channels. When less than average quality reflections are being recorded such a system as overlapping or limited cross feeding of the channels does tend to make the reflections stand out more clearly on the seismogram but such systems should be used only when the operators and interpreters of the data have complete knowledge of the resulting effects.

Filtering and grouping networks are common in modern seismograph work.



▼ Seismometer and Automatic Volume Control Amplifier Used in Portable Operations.

By these methods undesired frequencies and other effects can be partially eliminated.

The principle of multiple seismometer systems or the use of more than one seismometer per recording channel can not be easily stated but certain desirable effects of such a system can be readily indicated. When several seismometers are connected together into a single recording channel the net resultant is in general an average of the outputs of the seismometers of the group. Therefore if the pickups are placed over a small ground area the nearly true motion of the ground affects the group as a whole. This effect is often desirable because of the possible mechanical variation of the coupling of the ground connection with the individual instruments when a varying surface soil condition exists. Very often the mechanical coupling of the instruments with the ground is not uniform because of the variations of the top soil. The general response of the group seems to eliminate to a certain degree any poor coupling of the seismometers to the ground.

Another advantage of grouping seismometers into a single electrical output is that the resultant recording is more sensitive to the ground motion originating from the emerging reflected waves. It has been shown by various independent workers in seismograph research that in a general way the ratio of the reflection amplitude to the amplitude of the probable background of the seismogram is proportional to the square root of the number of instruments in the group. As an example, four seismometers per channel should approximately double the amplitude of the reflection phases as compared with the recorded background of the record. This theoretical result was obtained by working with probability. However, to theoretically increase this ratio by a factor of ten would require 100 instruments per group which obviously is not a practical thing to do in field work. General practice seems to indicate that one to six instruments per trace is the normal variation used by operators in routine field work.

The argument that multiple seismometers recording will eliminate the so-called "ground roll" and other background noises by destructive interference is not well demonstrated either theoretically or practically. In general these undesired background noises appear on the record in a random manner and therefore there is a possibility that some of this undesired background may be eliminated by destructive out of phase interference. The very opposite seems also possible, that some in phase reinforcements may increase the amplitude of the background. If there is an analogy between the random background of a seismogram and the ordinary noise most of us would agree that two similar noises are louder than a single noise but perhaps we all would not agree that two similar noises are twice as loud as one of the noises.

The number of seismometers used per channel in the final analysis is usually determined by the solution of the economic problem plus the desired results. Multiple seismometers in large numbers may affect the efficiency of a crew. This is especially true if conditions require extremely portable equipment.

It is claimed by some operators that by simultaneous use of several shot holes spaced according to a certain pattern desirable effects can be secured on the seismogram. This system may have possibilities but there is the disadvantage that the added cost of drilling and loading extra shot holes may offset some of the advantages which may be obtained by a less expensive method.

In conclusion regarding recording systems, because of its importance, it should be reiterated that operators and interpreters of the data should be thoroughly familiar with the system or systems used or serious misuse of the data may occur. Nevertheless, it has been clearly demonstarted that because of these so-called improvements in recording technique it is often possible to map the attitude and position of subsurface interfaces in areas where earlier shooting methods failed or gave data which were not conclusive enough to be of any value.

Computing Methods

The simplest methods of computing reflection data usually assume the velocity of seismic waves to be constant at all depths, or assume a different average velocity for each depth. While these assumptions give fair approximations in many cases, very considerable errors in computed dips may result. This error is introduced because of the failure to consider the appreciable curvature of seismic ray paths caused by the increase of velocities with depth. Field experience has demonstrated that the improved accuracy resulting from complete consideration of velocity increase with depth amply justifies any additional effort required to obtain accurate velocity data or in preparing computing charts and methods of attack.

The rapid depletion of simple and easily found structures is placing increasingly severe demands on the accuracy of reflection seismograph methods. The mapping of faults, possible unconformities, or steep dips in sedimentary rocks requires much more refinement in computing technique than was needed to locate many of the more obvious and well developed buried anticlinal structures discovered in the past by the reflection seismograph. For this reason any approximations used in computing should be scrutinized carefully. The magnitude of the errors introduced by approximations may easily be as large as the details sought and therefore vitiate all the effort expended.

Any computing method to be acceptable should fulfill the following general requirements:

1. The computing method should be simple, direct, and rapid so as to eliminate possibilities of errors and to allow a full understanding to all who are to use the final data.

2. The computed results should follow rigorously from the assumed velocity-depth function and the laws of wave propagation. This means that since the computed results are rigorous and consistent within the framework of the assumptions, the only error of interpretation will arise from the use of a velocity-depth function that differs from the true one.

This is not true of those computing methods in which the rays are assumed to travel in linear paths for the purpose of simplifying the computing. Such methods must be used with caution for the errors can become quite large. The assumption of linear ray paths and the use of velocity varying with depth is inconsistent from the beginning, because a varying velocity with depth of necessity introduces a curvature into the ray paths. This inconsistency of assumptions inevitably appears in the results and it is often found that when these assumptions are used, dips of correlated reflections do not plot in a consistent manner with the depths, or the horizontal distance from the shot point to the section of the interface giving rise to the reflection is not consistent with the dip and depth, depending on the type of approximation made.

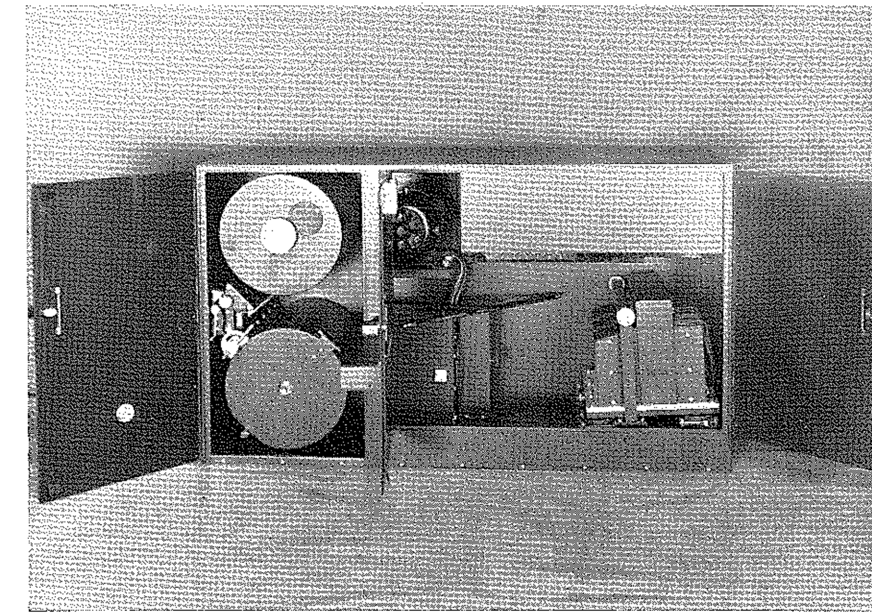
As evidence of the importance of the velocity-depth function in increasing the accuracy of seismograph surveys it is only necessary to mention that a well velocity surveying group has been formed in California. This group has measured velocities in practically all important wells drilled during the past one and one-half years in California. In this manner the seismograph operators participate in the expense of the well surveys and thereby secure the velocity data for their computing work.

Research and Development

During the past five years reflection seismograph equipment and technique have been continuously modified and improved. There is no reason to believe that the improvements and developments during the coming five years will not be as great, or greater than, in the previous period. Such advancement calls for an active and efficient research department. Many operating companies fully realize the importance of maintaining a definite research program, with a qualified staff and adequate facilities. It should be the policy of every acceptable contractor to incorporate the latest and most modern developments in his equipment and technique.

Drilling Equipment

The drilling equipment of any seismograph crew is a very important and integral part of its organization, because the cost of drilling operations amounts to one fourth to one half of the entire party operation cost, depending upon the type of rock drilled.



▼ Complete Recording Camera for Twenty-four Seismograph Traces Weight Approximately 40 Pounds.

Experience has shown that drills must be light enough to be very portable, fast in the field, and at the same time rugged enough to drill holes ranging from 100 to 1000 feet deep. With these points in mind anyone contemplating using a contract crew will want to investigate the drilling possibilities thoroughly. It is often desirable to have a second drill available for emergencies in case of a break down or of difficult drilling conditions.

Survey Progress

The number of profile set-ups which can be made by any field party depends upon several factors, the most important are the amount of trouble encountered in the field and the team work of the crew. The personnel of a seismograph crew should be carefully selected. With ordinary conditions in continuous profile or individual station shooting, parties average between twelve and twenty profile set-ups per day.

If reconnaisance work is being done the average reflection crew can cover approximately 100 to 200 square miles per month depending on the weather and transportation conditions. In continuous profile work approximately 30 to 50 miles of profile can be covered per month. Detail reflection work such as required to delineate geologic structures of low relief requires much more time and painstaking than in areas where the structural relief is greater. Approximately 15 to 60 square miles of area can be covered in detail per month.

Under conditions which require extremely portable equipment 3 to 9 instrument set-ups can be occupied per day. Usually the progress of this type of work is limited by the terrain and number of shot holes made available.

Cost of Seismograph Exploration

To the average engineer the cost of reflection work will seem relatively high but when compared with the drilling of dry holes the cost of the latter will be found much higher. From an information point of view a dry hole gives little geologic structural information as compared with the information which can be secured by a reflection seismograph program of equal cost.

For the cost of a single deep dry test in the floor of the San Joaquin Valley of California a single seismograph crew can be operated for approximately 20 months, in which time 600 to 1000 miles of continuous profile could be surveyed or 2000 to 4000 square miles of area covered in a reconnaisance manner.

The greater part of the cost of seismograph work is the expense of operation, i.e., salaries, field expenses, repair, gasoline and oil, depreciation, explosives, casing and patent costs. The normal contract seismograph crew consists of from 12 to 20 men as personnel of whom 4 or 6 men are chosen because of their technical ability and the others are to some extent men of certain trades. The truck equipment required for field transportation varies from 3 to 7 units.

A breakdown of the average expenses of a modern seismograph crew using 18 men, seven truck units and one automobile would in general be as follows per month:

Salaries of 4 geophysical engineers	$1000.00
Wages of 14 field workers	2100.00
General repair and upkeep	600.00
Depreciation of equipment	1000.00

Gasoline and oil	450.00
Supplies, etc.	275.00
Explosives	650.00
Patent rights	500.00
Research contribution	250.00
Overhead	150.00
Field expenses	300.00

TOTAL AVERAGE
COST PER MONTH $7275.00

Crews which use less truck equipment, fewer traces, and less men have total operating expenses varying from $4000.00 to $7000.00 per month. In addition to these costs often the operator must pay for land permits, surveyor, damages, etc. which usually runs the total cost to the operator from 6 to sometimes as high as 18 thousand dollars per month.

Severe price competition in seismograph services is a very short-sighted policy. When such competition controls the fees for services money is first taken from research and development programs which in the final analysis are the research and development of the client. If competition requires still further reduction the personnel is the next to suffer and finally for the lack of funds for the proper upkeep the condition of the equipment is impaired and the net result a degeneration of the quality of the services.

General Differences Between Seismograph Services

During the several years prior to 1940 the supply of seismograph services was less than the demand and discrimination among the various contractors was not considered to any large degree. With the supply rapidly exceeding the demand clients will begin to mark the differences between seismograph contractors. Some of these so-called differences may be recognized according to the following criterion. First, there is the fundamental purpose of the organizers at the head of a service. Are the men making up the nucleus of the organization in seismograph work mainly because it offered a good business opportunity to make money or is their purpose in organizing a service to develop further the science and profession already established and to unite the efforts of professional men. The answer to this question in general establishes the policies of the service. Second, the integrity of the organization is of paramount importance to the user. Once an individual has for selfish reasons disregarded the ethics of the geophysical profession, is no guarantee that he will not repeat such an offense should the opportunity arise. Third, the capability of the service is considered. This is usually judged by the experience and scope of operations of the contractor. In considering a contractor of several years of commercial work the ability of the organization as a whole seems easily established. Nevertheless, it seems that recent close scrutiny of clients or perhaps some other factor has caused the inactivity of a few apparently well established geophysical services.

It should be appreciated that a good seismograph service organization can not come into being by simply purchasing a set of equipment, securing an experienced personnel and then begin turning out surveys. In the first place little equipment of this type has appeared on the market which has been modern in all details and in the second place it is not often that a rapidly built up personnel will operate with mutual understanding and mutual tact throughout. The difficulties, trials, and trivial happenings in field operations require the utmost in tact, understanding, and the giving of credit where credit is due and vice versa. This requires that personal friction must be completely avoided.

The recognized first class seismograph services with few exceptions have been developed by years of experience and hard work of the men heading the organization. Since an adequate supply of equipment has not been placed on the market the first problem of a new organization is to design and test the type of equipment to be used. In some cases it has been possible to make certain short cuts in design by acquiring information on existing equipment. Then the technique of operating and the final interpretation problems have to be worked out. After the building of the necessary equipment and the development of technique a smoothly operating personnel is finally acquired.

Not all clients are alike in their demands of a seismograph service, therefore a variety of assumptions, technique, and types of equipment are possible. However, most all prospective clients base their judgment on a service by considering certain standards. Some of these factors are given in Table I.

The profound secrecy of the seismograph contractor toward clients and others interested is likely to be used to cover simplicity and lack of refinement rather than to safeguard the contractors interests in new and refined methods of approach in the work.

Personnel of the Seismograph Party

The prospective client for this type of scientific service will benefit from an examination of the experience record of the personnel of a geophysical contractor. Contractors sense the desire of the client to secure the services directed by men of broad geophysical experience and often offer advancement to geophysicists of other companies. A result of the policy of collecting specialized personnel to the embarrassment of other established geophysical companies is that often a dissatisfaction develops with the acquired individual and he holds back some of his information gained by experience for the fear that someone else would profit should he not withhold his knowledge. Then too often the company which acquires personnel in this manner becomes dissatisfied with their prize, and thus a number of conflicts may exist which are not always self evident.

Since the nature of geophysical work requires the undivided attention and effort of every member of the personnel from the placing of the explosives in the ground to the presentation and

(Continued on page 462)

Table I.
PERTINENT BACKGROUND FACTORS OF SEISMOGRAPH SERVICE ORGANIZATIONS

Claims on border line of possible accomplishments	Actual accomplishments in back of conservative claims
Low price of service	Quality and efficiency at slightly higher price
Extensive advertising	Modest advertising—funds diverted to research problems
Copied achievements from other geophysical operators thru acquired personnel	Original achievements in art developed and put into practice
Personnel collected from other existing organizations giving rise to highly competitive personnel organization	Personnel trained, organized and developed from basically well trained scientists working their way up through the ranks of the organization
Highly specialized personnel, observer has little knowledge of computing; computer little knowledge of field operations, etc.	Broad training of personnel accomplished by working up thru ranks, field work, assistant observer, observer, computer to party chief
Accomplishments in large expansion, world-wide service by established routine, great secrecy regarding fundamental equipment, technique and general operations	Accomplishments in pioneering recognized improvements in art, varied experience in attacking problems by research, cookbook methods of routine avoided, large expansion program second place to thoroughness and flexibility in adjustment to new problems

SUBSURFACE PRESSURE AND TEMPERATURE GAUGES AND SAMPLERS

By

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As the drilling for and producing oil become more of a technical problem, it is more necessary to secure sufficient and reliable information so that properties can be operated in an efficient and economical manner. In order to secure the information desired many kinds of measuring devices have been developed. Among the important developments have been instruments for measuring temperatures and pressures in oil wells. These instruments are run in the flow string by the use of a lubricator, stuffing box, steel line, depth measuring device and reel. To supplement the information that can be secured with these instruments several types of samplers have been developed with which a sample of well fluid can be taken at any desired place in the flow string and brought to the surface without changing the pressure on the sample. The subsurface data first obtained only for use by the research department have now many practical field and laboratory applications.

The practice of taking subsurface pressures, temperatures, and samples in oil wells has been followed by some companies as a regular procedure for several years. The information secured has proved to be of immense value. Now with more numerous plans and methods of producing oil and operating properties and the new problems caused by deeper production, the value, to the small as well as the large operator, of all obtainable subsurface information cannot be over emphasized.

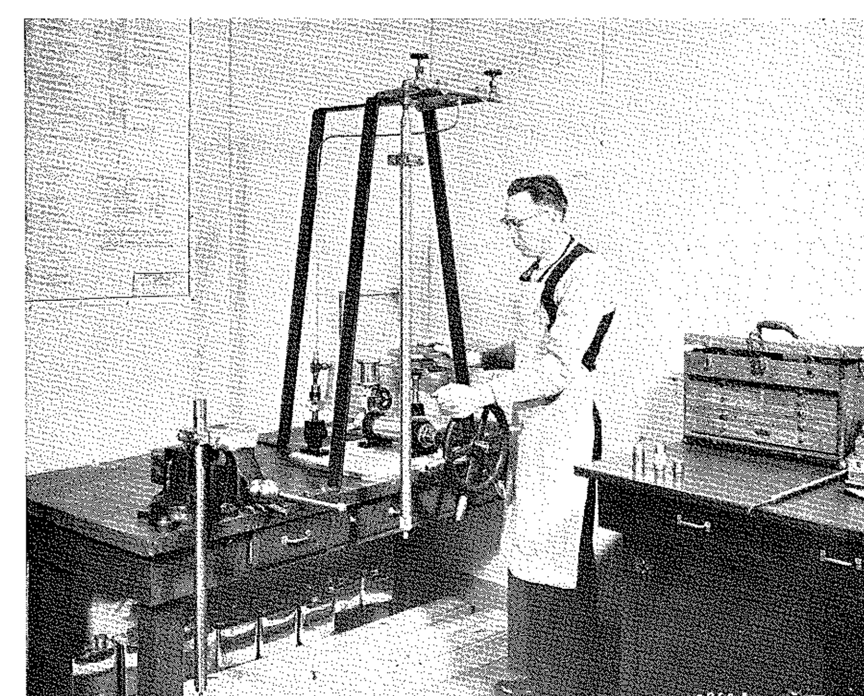
This article is to familiarize the operators and engineers that have not taken full advantage of subsurface information with some of the instruments available, the equipment required to make the surveys, the method used in running the instruments, and the possible application of the information after it is secured. The discussion of the subsurface instruments themselves will be limited to those developed by the Humble Oil and Refining Company as the length of this paper will not permit including all instruments that have been developed.

Subsurface Pressure Gauges—Humble Type

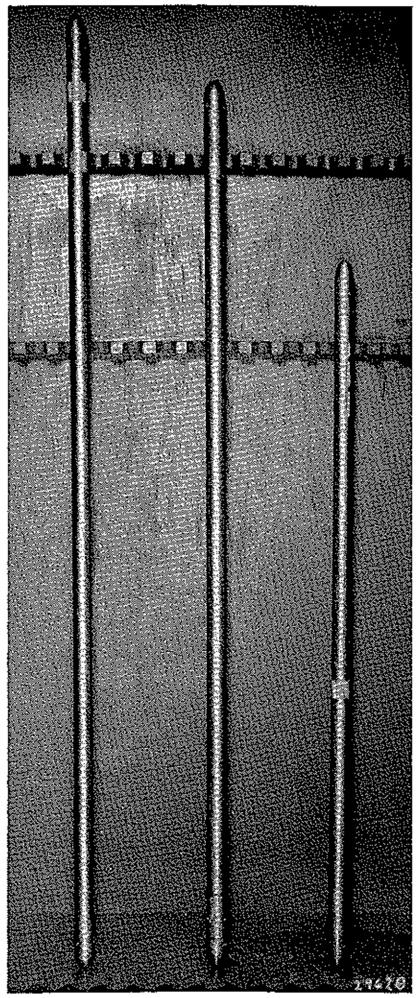
The Humble subsurface pressure gauge is very simple and satisfactory in its operation. The well pressure is admitted into the inside of the gauge at the top where it acts on a piston against the tension of a helical spring. The lower end of the piston extends through a stuffing box into the lower section of the gauge which is kept at atmospheric pressure. The stylus mounted on the lower end of the piston records on a chart the amount of extension of the spring. This extension is a measure of the well pressure. The gauges can be secured equipped with a suitable spring for measuring the desired pressure with a great degree of accuracy. It is advisable to use a spring that will give the maximum extension for the maximum pressure that will be encountered in order to read the chart record as closely as possible. If the same gauge is to be run in wells having a large range of maximum pressures, it is necessary to have several spring sections or to change the spring and calibrate the gauge. Springs are available for 1000, 1500, 2000, 3000, 4500, 6000, and 7000 pounds maximum pressures. The gauge can be assembled as a maximum pressure recording type without turning device, which is used for calibrating purposes and for an occasional single approximate subsurface well pressure. A maximum reading thermometer can be secured for use with this gauge.

The second and most used gauge is of the recording pressure type equipped with a clock operated turning device which is used to obtain a series of subsurface pressures on a chart for definite time intervals. When this series of pressures is taken both going in and coming out of the hole the chart obtained will be a pressure traverse and will give the maximum information and accuracy. Either a maximum recording thermometer or a recording type thermometer with clock-operated turning device can be secured for and operated with the recording type of gauge.

In addition to the information secured by the subsurface pressure gauge and subsurface thermometer, it is necessary to take certain surface measurements in order to have complete data. The surface readings required are as follows: Depth of instrument in well, secured by a measuring device; tubing and casing pressures from pressure gauges; production of oil and



▾ Laboratory View.



▼ Gauge, Sampler and Recording Thermometer.

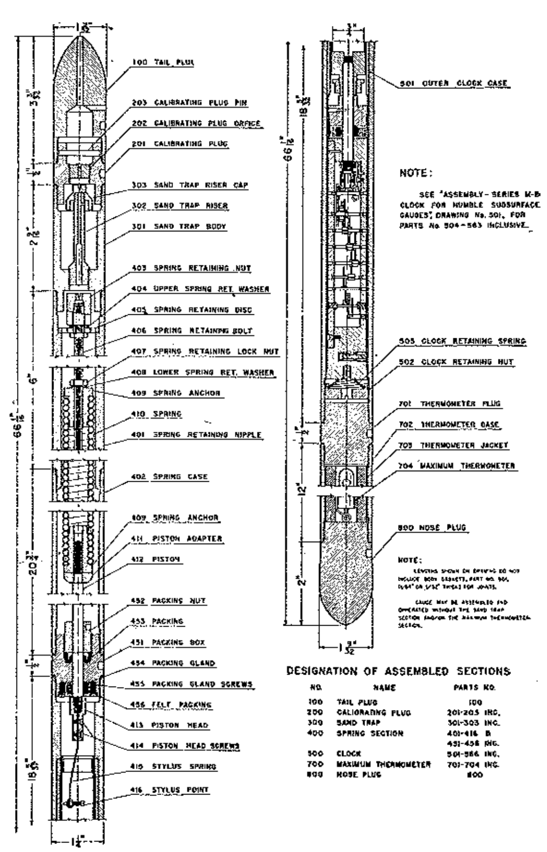
water by measurements or meters; and production of gas by meters.

Process of Running Static Gradient:

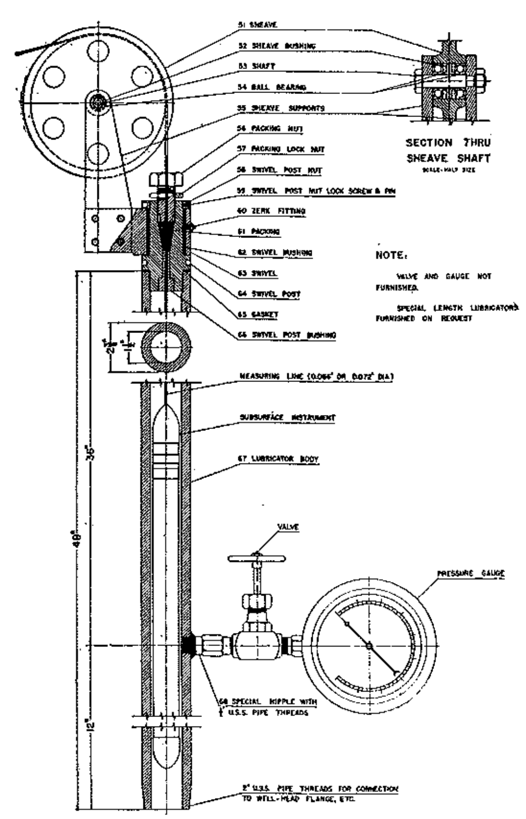
When it is required to run a static gradient, shut in pressure test, the well is shut in for a sufficient length of time to allow the pressures in the producing formation and the well to become equalized. The recording type of subsurface pressure gauge is run with the recording type of thermometer to the desired depth stopping at intervals to record the depth and to provide time for the stylus to record the stop on the chart. On the way out with the instrument the same stops are made at the same depths and the depths recorded. The chart is removed from the gauge and from the thermometer and the information is plotted on coordinate paper with the help of a chart scanner, the spring calibration curve, the thermometer calibration curve, and the temperature correction curve by using pressure per square inch as one ordinate and depth in feet as the other. By extending each of the lines through the plotted points until the lines intersect, and if there is gas, oil, and water in the hole, a gas gradient, oil gradient, and water gradient will develop. This curve will show the pressure at the well head, the fluid level and the water level. The slope of the gradients will give the density of the respective columns. To get the pressure at datum the fluid gradient is extended to the middle of the known producing formation, then a line is drawn through this point with a slope equal to the density of the reservoir fluid to where it intersects the datum line. By projecting this point the pressure at datum is read.

Procedure for Making Flowing Test:

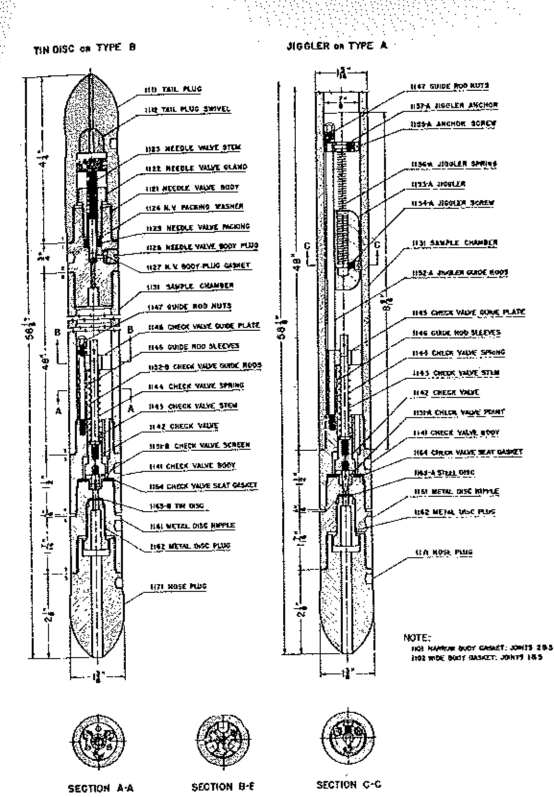
To make a flowing test, the well is shut in and the static test run as described. The clock is checked to see that it is running. The gauge is then run to bottom and the tubing and casing pressures recorded. The well is opened, the time, tubing pressure and casing pressure recorded. The time the oil reaches the tree is recorded and a bob tail gradient is run near bottom at intervals of 5, 10, 20, 40, etc. minutes after the well is opened to obtain a draw down curve. Time, tubing pressure, and casing pressure are recorded each time the gauge is returned to bottom. During this process the gauge is pulled up approximately 500 feet from bottom and lowered back to bottom several times, stopping momentarily two or three times in each direction but having the gauge at the lowest point for each reading time. This portion of the chart will give the pressures at intervals of time which in conjunction with the amount of fluid produced will give the bottom hole pressure for a definite rate of flow. By taking this portion of the curve for different rates of flow, the well potential and the rate of flow for any bottom hole pressure can be determined. After the tubing and casing pressures have become constant the flowing gradient is run, starting from the top and making a round trip stopping at intervals, the frequency of which depends upon the amount of information desired. Usually at least four stops going down in the last 1000 feet of hole and three coming up are required. During the test the production should be recorded at thirty minute or other intervals of time after the first oil arrives at the separator. The oil density and gas density are also recorded at these same intervals. It is necessary to consider the change in the amount of oil in and behind the flow string when the amount of production is plotted. To do this a tabulation is made of the test data so the barrels of oil in the tubing and behind the tubing can be calculated from the tubing head pressure, casing head pressure, and the bottom of pay pressure by the difference in pressure head divided by the slope of the shut in oil gradient. This value is feet of oil which can be converted to barrels of oil by casing volume tables and then decreased by the shrinkage factor to get barrels of oil at the surface. When this correction is made to the amount of fluid produced as measured in the tank the actual amount of production is obtained. The information secured is plotted on coordinate paper with a triple scale of pressure in pounds per square inch, barrels of fluid and percent of water as one ordinate and time as the other ordinate. The fluid produced by the formation is plotted by calculating the shrinkage factor and correcting the fluid as measured in the tank accordingly. The percent of water as found by shake out or other test, the fluid produced as measured in tank and corrected, the fluid produced by formation, tubing head pressure, casing head pressure, and bottom hole pressures are all plotted as separate curves. The productivity factor can be calculated and is the rate of total fluid produced by the formation divided by the difference between the shut in and the flowing bottom hole pressures and is designated in barrels per day per pounds per square inch pressure referred preferably to the mean pressure at the sand face. The specific productivity factor is the productivity factor divided by the feet of producing formation and is designated in barrels per day per foot per pounds per square inch pressure.



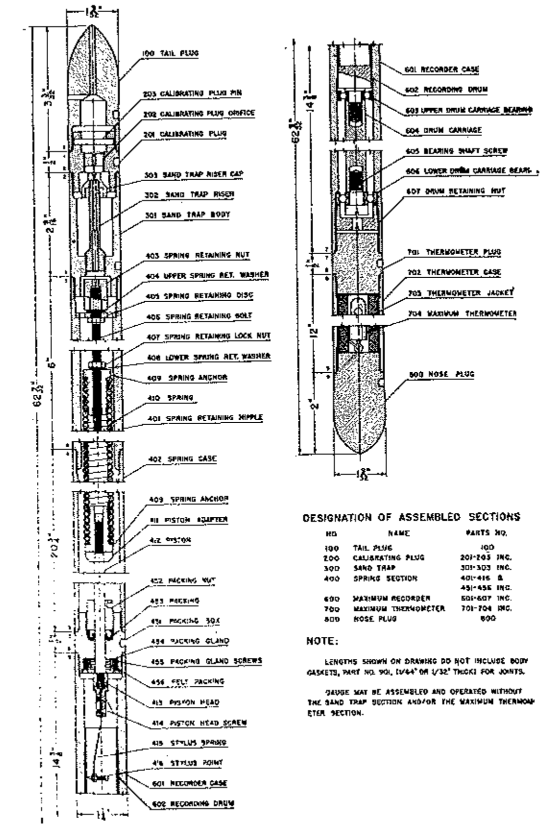
▼ Subsurface Pressure Gauge, Clock Recorder Type.



▼ Stuffing Box & Lubricator.



▼ Subsurface Sampler.



▼ Subsurface Pressure Gauge Assembly, Maximum Recorder Type.

The procedure just described is for a test from which the maximum information is desired. Other procedures can be followed or only part of this procedure used if only a part of the information is desired. By periodic running of the complete test as described basic information is secured which will assist in determining

- Gas oil ratios
- Percent water produced
- Fluid produced in tank
- Fluid produced by formation
- Static fluid level
- Static oil level
- Density of fluid column
- Subsurface pressure referred to any datum
- Productivity factor referred to any datum
- Specific productivity factor
- Well potential from draw down curves
- Minimum flowing pressures
- When artificial lift will be required
- Amount of fluid to be lifted
- Size of pumping equipment required
- Presence of water in the bottom of the hole
- Excessive withdrawals
- Advisability of reconditioning wells
- Existence and movement of gas cap
- Estimate of oil reserves
- Best well spacing
- Direction and speed of migration and behavior of fluid in reservoirs
- Probable area of best production
- Development program
- Effective permeability of formation
- Shrinkage value of fluid
- Future pressure drop for various rates of flow
- Reason for changes in well performance
- Compressor requirements for repressuring or flowing
- Basis for unitization

Undoubtedly in the future other important uses for these data will develop as well as the more general use by the small as well as the large companies.

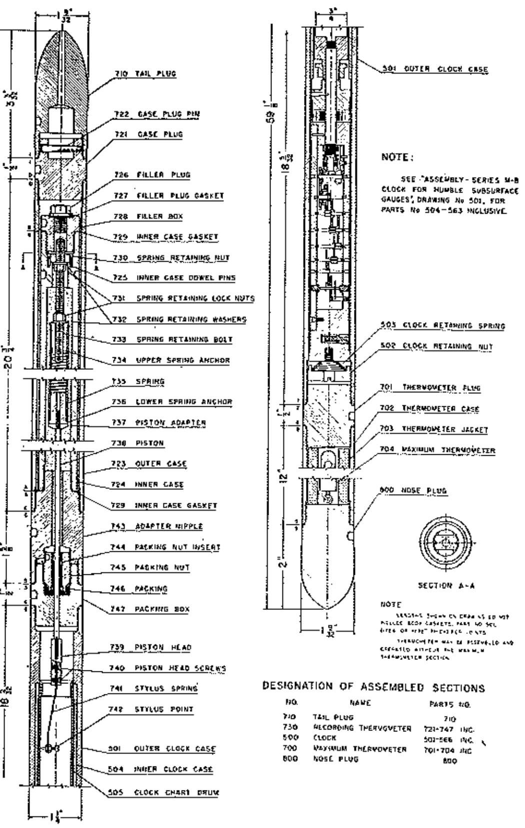
Subsurface Recording Thermometer—Humble Type

The Humble type of subsurface recording thermometer is designed for use with the same recording clock as used with the subsurface pressure gauge. The instrument consists of a mercury filled cylinder equipped with a piston operating through a stuffing box against the tension of a helical spring. A stylus is mounted on the lower end of the piston and records on a chart the amount of extension of the spring. This extension of the spring is a measure of the expansion of the mercury which in turn is a measure of the increase in temperature.

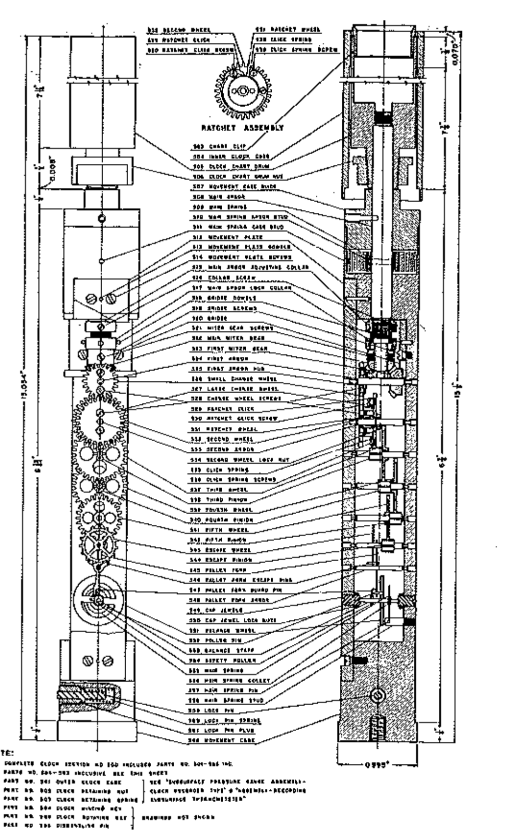
Procedure for Running Temperature Traverse:

The procedure of running a temperature traverse in a well is similar in general to the method of running the subsurface recording pressure gauge. The same stuffing box, lubricator, wire, measuring device, and reel can be used or it can be run in special containers on pumps, formation testers, or with other instruments. The instrument is calibrated and run in the well. Stops are made periodically both going down and coming out and a record kept of the time the instrument leaves each stop. By regulating the length of time the thermometer is stationary at each position so that the clock used will turn the chart a sufficient amount, a good record will be obtained. By making the same stops on the way out differences due to thermal lag and temperature drag are cancelled. The least length of time required for the instrument to reach thermal equilibrium depends upon the well conditions at the time of the test and must be determined experimentally. In most instances one minute will be sufficient.

The extensions on the chart are read using a chart scanner and are converted to temperatures by using the calibration curve. For the increasing temperatures the increasing temperature calibration curve is used and for decreasing temperatures the decreasing calibration curves is used. The mean of



▼ Subsurface Recording Thermometer.



▼ M-B Clock for Pressure Gauge or Thermometer.

the going in and coming out temperatures are used to draw the final gradient after a correction of three-fourths degree Fahrenheit for each 1000 pounds per square inch pressure has been subtracted.

In addition to the use of temperature readings in measuring subsurface pressures, temperature traverses are used

- To locate height of cement behind casing
- To determine presence of water in producing formation
- To locate source of water coming through casing or from formation
- To detect water flow and water movement behind casing
- For geological correlation
- For reservoir content studies of space volume relationship
- For studying mud performance
- For cementing operations
- For chemical treatment of wells or plugging water sand
- For thermodynamic studies

Other uses for temperature information will develop.

High Pressure Subsurface Sampler—Humble Type

The Humble type of subsurface sampler is designed to secure samples of the well fluid from any desired depth and retain the sample under the same pressure. The instrument consists of a cylindrical chamber equipped with a means for allowing the fluid to enter at any desired time and a means for keeping the sample in the cylinder under the same pressure until it is withdrawn from the hole and taken to the laboratory. The sampler is made with two arrangements for admitting the sample to the evacuated cylinder. The most used is the jiggler type which can be run to the desired depth and opened by bouncing the instrument slightly. This bouncing causes a weight suspended by a spring to strike a sharp pointed tool which in turn punctures a metal disc and allows the well fluid to enter. When the pressure becomes equalized inside and outside the cylinder a spring forces a valve to close and the sample is confined until it is removed from the sampler. The disc type of sampler has a disc which will rupture after it is subjected to the well temperatures and pressure for a predetermined length of time. When this disc breaks the sample is admitted and the same valve arrangement as previously described confines the sample under well pressure.

Procedure for Taking a Subsurface Sample:

The subsurface sampler is run in the well to the depth from which the sample is to be taken after the well has been prepared so that a representative sample will be secured. The same reeling and measuring equipment as used to run the subsurface pressure gauge is used for this work. After the jiggler type sampler has been stopped at the desired depth it is bounced slightly to allow the fluid to enter the sampler and allowed to remain stationary for a few minutes until the sampler is full and the valve closed. The examination of the sample is made with the assistance of a mercury pump and a valve lifter to vary the pressure and volume inside the sampler by measured amounts and to remove amounts of fluid from the sampler so that other tests can be run on the fluid. A water bath is used to control the temperatures and in case only a part of the sample is to be removed from the sampler for analysis an agitating means is required so that the sample removed will be representative. A large amount of information can be secured from a bottom hole sample such as: viscosity under various conditions of temperature and pressure; pressure volume temperature relations; saturation or bubble point pressures; total amount of gas dissolved in or associated with the oil; the quantity of gas liberated under various conditions of temperature and pressure; the shrinkage of oil resulting from the release of its dissolved gas.

This is just another important link in the chain of technical data required for developing and perfecting producing procedures in order to operate in the most economical manner.

Conclusions

The wealth of information that can be secured by the periodic subsurface temperature and pressure surveys in conjunction with the information secured from bottom hole samples will, if properly used, assist materially in the economical operation and will contribute in no small manner to increasing operating profits by

1. Increasing the ultimate recovery.
2. Increasing the flowing life of wells.
3. Preventing premature and uneven water encroachment.
4. Reducing expenditures for equipment and deferring purchase of equipment until it is actually required.

The cost of the equipment necessary for conducting these tests and the cost of maintaining an organization for taking and interpreting the data is relatively small for a company with any appreciable amount of production or interests when the possible returns are considered. For the companies not large enough to maintain such an organization, a service is available by competent engineers who have the necessary equipment and experience to do this type of engineering on a contract or consulting basis.

INTERPRETATION OF SEISMOGRAMS

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INTRODUCTION

The entire system of interpretation of data obtained by seismic prospecting is designed to reduce these seismic data into geological pictures. This should be the fundamental criterion for one who wishes to interpret such data.

The plan of this paper is to discuss some of the factors involved in the interpretation of seismograms. Interpretation is accomplished both quantitatively and qualitatively. The final reduction of the interpreted data to contour maps and reports will not be included in this discussion.

Assuming the interpreter to have a background in the theory of seismic wave paths and wave propagation, there remain certain prerequisites for every survey.

1. A study of the geologic section, regional structural geology, and stratigraphy of the area completely encompassing the survey, and supplemented by well data where possible.
2. The physics of the survey.
   a. Average and differential velocities through the geologic section, and their lateral variations.[1]
   b. Method of shooting, location of shotpoint and geophones, and geophone intervals and hookup as determined by experimentation.
   c. Filter action, energy transmission, densities, and elastic constants of the geologic members, if possible.
   d. Surface aeration (weathering), and shot hole aeration.
3. Past experience in areas of similar seismology and geology.

Although this last item is not always possible yet it is often the most important aid. This is especially true when interpretation transcends theory and becomes a matter of judgment alone.

DATA CORRECTIONS

Qualitative Interpretations

A seismogram is the graphical representation of the motion of the elastic waves as they reach the surface of the ground in the region of several detectors connected in series with the recorder. The oscillations of the formation in immediate contact with the detectors are recorded as sinusoidal wave forms on photographic paper. The character of the recorded wave form is directly proportional to the character of the ground motion at the detectors, and modified by a proportionality factor which is a complex resultant of the physical constants of the entire recording channel. A qualitative interpretation of seismogram character must give full weight to these modifying constants and variables. That is, the apparent character must be reduced as much as possible to a true representation of the ground motion.

Quantitative Interpretations

Quantitative interpretation is classed under the head of computing. Computation of dip and depth data is the mathematical evaluation of the space positions and directions (angularity) of the reflecting horizons. This is accomplished by a geometrical consideration of the wave paths and arrival times of the reflections.

Reduction to Datum

Before the calculations can be made, certain time corrections must be made. In any given area all calculations are made to a datum plane so that corrections are made in two distinct steps.

1. Reduction to an instrumental datum.
2. Reduction to a geological datum.

It may become necessary to change some of the instruments during a survey, thus resulting in a phase shift. For example, a new type amplifier may be introduced. Then a shot must be taken with the new and the old amplifiers in parallel. The difference in the arrival times of reflections through the two amplifiers is the amount of correction to be added or subtracted for calculations involving the new amplifiers. Other time corrections which may be made are for parallax[2] and for phase differences between each recording channel.

The next step is to reduce the seismogram to a geological datum. The most common practice is to correct for weathering and use sea level as the datum thereby eliminating the effect of elevation. This correction is entirely for time or its equivalent in terms of depth.[3, 4, 5, 6, 7] Certain other corrections may be introduced depending upon the method of shooting, method of computing, and geological conditions. A few of these are:

a. Aeration in the shot hole, resulting in a variation of the initial propagation velocity between shots.
b. Lateral variation in average velocities because of the changing thickness of the weathering and difference in depths to the same reflecting horizon from shot hole to shot hole.
c. Angularity correction which corrects for the difference in the angles of incidence to each receptor.[8]
d. Reduction of data by the method of least squares.[9, 10, 11, 12, 13, 14]

CALCULATIONS

Velocity

After all the time and depth corrections have been made the computer calculates the depths to the various strata represented by the reflections. The methods of calculation are all based upon the fundamental seismic path representation. The simplest methods employ a straight line wave propagation, and the problems are solved by the Pythagorean Theorem. Other methods involve a curved-ray interpretation of the path or a combination straight line and curved-ray interpretation. The second factor in computing depths is the velocity consideration. From well-shooting data or refraction profiles, the velocity variations with depth can be determined. Then, retaining simplicity and accuracy, the type of velocity variation to be used can be chosen from the following classification:[1, 7, 8, 10, 19, 20, 25]

1. Average velocities.
2. Differential velocities.
3. Velocities expressed by an equation (curved-ray).
   a. Linear increase of velocity.
   b. Exponential increase of velocity.
   c. Hyperbolic, elliptical, or parabolic wave paths.

Dip

Dip calculations may be made from either dip charts or direct algebraic computations. Dip may be considered in two dimensions (along profile of shooting) or in three dimensions.[19, 22, 23, 26]

The most varied calculations are those used for weathering. Each company has its own method many of which are secret. The calculations depend, of course, upon the method of shooting, but a general outline might be made:[3, 4, 5, 7]

1. Refraction profile.
   a. Vertical ray.
   b. Inclined ray (high speed weathering).
   c. Shallow reflected wave (straight or curved rays)
   d. Curved refracted ray.
2. Shot hole geophone.
3. Direct ray geophone (short distance geophone).

Each of these methods can also be varied by changing the shot hole and geophone placement.

CHARACTER OF WAVES

Before discussing character reduction we should define and evaluate "character." For our purpose we shall distinguish between "apparent" and "actual" character. Apparent character is the graphical "appearance" of the wave form as recorded on a seismogram.[24, 27, 30] This definitive appearance is the result of the recording of a series of reflected energy impulses. This wave pattern consists of:

1. Individual reflection wave forms (including phase change).
2. Banding.

The wave form of an individual reflection is outlined by:

1. Onset conditions, which include the first arrival of the reflected energy and its imposition upon the wave form of preceding oscillations.
2. Development of the wave form including the amplitude relations between peaks and troughs, frequency of each cycle, damping (duration of the reflection), and intensity of energy received in proportion to the amount of dynamite used.

A phase change is the result of the imposition of the first energy impulse upon the wave form of the reflection preceding it or stray energy if the reflection has been completely damped. Since the reflection will rarely be in phase with the preceding oscillations, the phase change will show up as an inflection point or slur in the total wave form.

Banding is the appearance obtained when several reflections arrive at very short time intervals, thus forming an energy group. Several such groups are usually present on a seismogram and are separated by intervals of relatively small motion.

Actual character is the theoretical wave form of the true ground motion. It is deduced by correcting and reducing apparent character for the modifying constants of the recording channels, but in practice is very rarely done.[28, 29]

INSTRUMENT SETTINGS

When first experiments are completed on a new survey, the type of instrument settings to be used is fairly well established. That is, acquired data show at what frequency to peak the amplifiers and what frequencies should be filtered out. The geophones have their best response at a certain natural frequency and damping coefficient. The galvanometers or harp strings are also set at a certain natural frequency. These constants,[15, 27, 28] however, may vary appreciably within a short time and the result is an appreciable character transformation. If the response of any one or more component parts of the recording channel changes, then the wave pattern of any given type of imposed energy will change, and this transformation tends to make correlation more difficult. The solution is to keep these physical characteristics adjusted to their constant values as much as possible.

Changes in wave patterns because of the method of shooting and by changing instrument settings are now being made use of and it is only in this way—to now—that a fairly accurate picture of true ground motion can be conceived. The idea is either to delineate complex seismograms by reducing the wave patterns to varying phase relationships or to remove as much stray energy as possible from the wave forms,[16, 17, 18, 24] and, lastly, to make the geophone as much a part of the ground as possible (e. g. decreasing the weight of the mass).

The variation in the wave pattern, because of changing the instruments, can be analyzed only by a direct comparison of two shots at the same hole and depth using first the old instruments then the new. This direct comparison will show certain features of the wave pattern.

1. Effect of instruments on reflection frequency and filtered frequency range.
2. Effect on the separation of reflected energy impulses from stray energy and ground-roll.
3. Effect on the duration of reflections and type of damping.
4. Effect on the sharpness of inflection points as peaks, troughs, and phase changes.
5. Effect on amplitudes or the intensity of energy received.

REDUCTION TO A GEOLOGICAL DATUM

There remains, now, the most difficult portion of character reduction, and that is: reduction to a geological datum. The datum plane to be used is the base of the weathered layer. This constitutes eliminating the effects of weathering and elevation changes on the seismic wave path, both at the shot point and the receptors. This is especially true for shooting in swamps or on the bay along the Gulf Coast.

These effects are not usually considered in areas of fairly uniform surface conditions, but a knowledge of these weathering effects will aid in determining the method and depth of shooting. This knowledge can be obtained only through actual field experimentation. Certain theoretical background is necessary, however, so as to better understand the "why" of these effects.[19, 21, 29, 31]

Character transformations in passing through the weathering layer may be enumerated as follows:[19, 32]

1. Resonance.
2. Phase shift.
3. Double energy propagation.
4. Absorption, dispersion, and scattering of energy.
5. Accentuation, attenuation, and filtering of certain frequencies.
6. Recurrent energy (reflections from base of weathering).

These effects will be described by citing special cases:

In parts of southern Louisiana where the surface formations are only slightly indurated and marshy, the weathering layer is jelly-like in consistency and records indicate that it acts as a high frequency filter, thus low frequencies are accentuated. The absorption coefficients are high and where the weathering is thick, large charges of dynamite are necessary. The emerging wave does not approach a vertical as it does in eastern Colorado and similar areas, so that weathering computations should consider this even to the extent of a curved ray interpretation. The initial energy is a compression, then a secondary lagging impulse is generated as a result of the expansion of the gases. This is especially true for shooting in swamps or on the bay along the Gulf Coast. The records often show a running together of the reflections with little or no separation of the initial impulses. Such a feature is one of the forms of resonance and causes much difficulty in correlation.

In some places along the Gulf Coast experimentation shows that a greater energy output may be obtained by shooting in the weathering, others at the base of weathering, and still others require shooting considerably below the base of weathering. These are all a result of the variations in the absorption coefficients.

In parts of northern Louisiana the surface stratum is a clay and overlies a sand. By actual experience it was found that good records could be obtained by shooting in the clay which is above the base of weathering. Shooting in the sand below the base of weathering resulted in records which showed no definitive character.

In eastern Texas a series of creek bottoms were encountered in a seismograph survey. Whenever the geophones were placed in a creek bottom the seismograms were so broken up in character as to be impossible to correlate. Evidently the character was altered by the weathering rather than by subsurface features, such as faults, as shown by the consistent association with the creek bottoms.

In the Bahrein Island difficulty is encountered not only in getting energy propagation but also definitive records. Correlation is difficult and it is likely that a great deal of character transformation takes place in the surface sands. The author suggests that since the sands are so loose, wave propagation may be accompanied by a gliding of the sand particles along each other thereby loosing much energy and modifying the wave forms.

A shot of the order of fifty feet below the base of weathering, in parts of north Texas, will result in reflections whose character will change from shot point to shot point. The character change is indicated by a shifting of the phase change and/or resonance. The type of the phase change also varies considerably. This all results from some of the energy of the shot passing upward and then being reflected downward from the base of weathering. This recurrent energy has a slight phase shift and time lag with the initial reflected energy which passed downward from the shot hole.

The last feature involves the combined effect of weathering and elevation. In southern Arkansas and also Santander, Colombia, in South America, the best geophone placement lies along the topographic contours in the valleys. The tops of ridges and knolls have a greater thickness of weathering so that if the geophones are placed in a straight line, elevation disregarded, or along the contours of the ridges the records obtained are very poor.

CORRELATION OF STRATA

To this point we have dealt with a quantitative analysis of seismograms, whereas, the qualitative analysis of a seismogram consists of its correlation with others as well as its geologic correlation. We may define correlation as: the contouring of geologic strata, in any given area, by the equivalent reflections of these strata. This definition is also the basic theory of correlation, meaning the direct comparison of reflections (and their identification) from one seismogram to another which seismograms are usually obtained by spaced shooting. The classical analogy to the correlation of seismograms is the correlation of well logs.

Although this discussion will be a study of the component parts of correlation, it must be kept in mind that interpretations can be made only after as many aids, tricks, and methods as possible have been used.

A seismogram contains several lines or traces (five or more) which have irregular sinusoidal wave forms. The method for finding those portions of the wave form indicating reflected energy impulses is to detect inflection points or slurs in the wave form followed by increased amplitude. Neither of these two features is infallible and care must be taken to distinguish reflections from stray energy, refracted energy and ground roll. The following five factors have distinguishing characteristics in reflections:

1. Frequency of the wave form.
2. Consistency of the wave form from one seismogram to another.
3. Variations in amplitude.
4. Duration.
5. Step-out between traces.

WAVE REFLECTIONS

The general physical elastic constants of the earth's crust are such that when a complex wave passes through the subsurface strata most of the frequencies are filtered. The reflections obtained from shooting a charge of dynamite range in frequency between forty and sixty cycles per second (regardless of area), whereas stray energies such as wind, blastophone, and rain have much higher frequencies. If the same type of a reflection is present on the records from several shot points and has approximately the same wave forms and arrival times then the reflection is consistent. Nearby falling objects or burrowing animals will cause wave forms that are "apparent reflections" but these reflections are inconsistent. Reflected energy arrives at almost the same time at all the geophones even though the geophone spacing is comparatively large, but refracted energy will show an appreciably large amount of step-out or difference in arrival times between geophone traces. If the geophones are set near a sixty cycle electric line the records may show induced energy approximating a resonant record. This wave form will show no damping, slurring of phase changes nor amplitude changes. Most geophones are critically or near critically damped so that the duration of a reflection is limited to one or two cycles. If the ground, however, is in resonance with the shot point frequency or the reflected energy then a beat frequency is recorded and the reflections may last four cycles or more. A reflection will indicate the composite damping of the geophones and reflected energy in the amplitudes recorded as well as in the duration of the reflection recorded. That is, a small increase in amplitude usually follows the phase change and this in turn is followed by a peak or trough of a much greater amplitude, after which the reflection is almost completely damped out.

After detecting the reflections it is necessary to pick their arrival times. Apparently it is best to pick the point of the first arrival of the energy which is the point of inflection of the phase change. Throughout any given area the wave form of the reflection varies sometimes obscuring the phase change and often shifting the phase change. To overcome this a later phase position is chosen, usually the first peak or trough after the phase change. It is also important to pick a consistent phase position as close to the phase change as possible because the reflection frequency is nearly constant only for the first cycle.

SUPPLEMENTARY CHECKS

The reflections to use for correlation must arise from consistent geological strata, should have enough amplitude to be readable, and have fairly consistent wave forms. Having chosen the reflections to be used for correlation and the phase positions to be used it is then necessary to relate the reflections to their corresponding geological strata. The best method is to shoot a velocity-depth determination for a well in or near the survey or, if possible, for several scattered wells. An alternative or supplementary method comprises shooting a travel-time refraction profile. Supposing the well data to be available, the reflection records at the well are compared to the velocity-time curve, well log, and the Schlumberger curves and from a study of changes in porosity, resistivity, and formation contacts, the main reflection horizons may be chosen. That is, for example, where a large change in resistivity (and often in porosity) occurs or a definite geological contact (e. g. shale-sand or shale-limestone) is encountered a strong reflection may be expected. These reflection-geological comparisons may be checked by a mathematical comparison of the reflection depths chosen, their recorded arrival times (corrected to base of weathering), and the velocity-depth curve. It is not necessary to have the velocity-depth data when approximate velocities are known since by trial and error the reflection-geological comparisons can be made, then checked by the approximate velocities and, finally, the true velocities are calculated from the seismogram data and reflection depths chosen.

The art of correlation lies in the next step. A general description of the reflections chosen is made based on several identifying characteristics:

1. General (type) wave form of each reflection.
   a. Type of phase change.
   b. Duration and damping.
   c. Amplitude variations.
   d. Phase position of main energy input.
2. Time intervals between reflections and banding appearance.
3. Relations between main and minor reflections.

Any or all of these features change throughout a survey but are used inherently in identifying the same reflection on different seismograms. Much of the character of a reflection depends upon the phase position of the main energy input. This phase position is indicated by the peak or trough with the greatest amplitude, and it may be noted that a reflection with the greatest energy breaking upward (large peak) is 180° out of phase with a reflection breaking downward (large trough). From theory and a knowledge of the geological contacts one can determine whether the type reflection should be a compression or expansion.[20] Many interpreters choose some of the best records throughout a survey as guides for correlation since they show the most definitive character as outlined above.

CORRELATION OF DATA

The correlation proper is now a direct comparison of seismogram to seismogram throughout the survey. The easiest correlation can be obtained by laying the seismograms side by side in the linear order of their respective shot holes, remembering that two records separated by a great distance may be more similar in appearance than two from adjacent shot holes. Since geology is fairly uniform then the corresponding reflections of two different records should have approximately the same corrected arrival times. For example, if reflection A on one record arrives several hundredths of a second later than on another record then a second reflection B should do the same unless a fault is present or A and B are separated by an unconformity or the geologic section is varying in thickness. In these exceptions a knowledge of the stratigraphy and a comparison of the wave forms are also necessary.

INTERPRETATION OF RECORDS

There are several ways to correlate records but the most prominent one is the direct comparison of two records laid side by side. This method may be modified by visual aids, for example each reflection phase is marked with pencil and these impulse lines are correlated from one record to another. This marking of the impulses minimizes the confusion of comparing sinusoidal waves. In another method, described by Dr. C. A. Heiland,[34c] the actual depth to each energy impulse is plotted and a profile graph is made. The general trend can then be noted and the strongest reflections correlated graphically. The reflections on a record may be accentuated in appearance if the record is viewed along a plane almost in line with the face of the record. Some interpreters, when correlating difficult records, make a tracing of one record and lay it on top of the other records by which means corresponding wave forms may often be identified.

Many companies obtain two or three records at the same shot hole, having different amplitudes and varied instrument (filter etc.) settings. In these cases correlation may often be accomplished in part by one record of low amplitude and the remainder of high amplitude. The character of a seismogram may be changed by varying the instrument settings and the depth and amount of charge used. With respect to the type of explosives used the author has found only one important variant and that is "time delay" in determining the moment of the shot,[33] but the rate explosive propagation may possibly have an effect upon the initial impulses of the reflections. In some areas it may also be necessary to vary the distance from the shot point to the geophones, thus shooting two or three different spreads at the same shot point. It may be seen, then, that the ease of correlation is dependent upon certain factors that can be modified and one that cannot.

1. Geophone spacing and depth of burial.
2. Distance between shot point and geophones.
3. Distance between shot points and their direction of shooting.
4. Depth and amount of the shot and type of explosive.
5. Instrument settings and characteristics.
6. Geological structure, stratigraphy and weathering.

The last factor may sometimes be overcome in difficult surveys by a trial and error method. After as much direct correlation as possible is made depths are estimated for the "unreadable" records by logical guesswork based on geological trends and associations and past experience. Then the records are recorrelated with an attempt to find reflections corresponding to the estimated depths. In this manner it might be that only one reflection may be found but it may be the key for further correlation or a substantiation of assumptions. An important guide to correlation is found in dip-shooting. From dips alone the trends of the formations (reflections) may be determined and faults detected by abrupt changes in dip (both angularity and direction).

Since seismology is a geological tool then the weapons of the geologist can all be used and usually profitably so. Thus in any given area it is well to have aerial photos and topographic maps. With these many faults and structural highs or lows may be detected as surface traces.

One of the best tests for the accuracy of the survey and for finding errors in correlation is to keep a basic control system. The lines of shooting are closed in the same way that transit traverses are, forming complete loops of shot points.[11, 14] In many areas there are also a sufficient number of old wells to use for checking the correlations.

CAUSES OF BAD RECORDS

The geological causes for bad records are numerous, many of which cannot be detected. Faults are one of the biggest causes of bad records, in fact to such an extent that in certain areas records showing broken character accompanied by low frequency reflections and reflections that show up on only part of the traces, are used as an indication of a fault. This reasoning may be checked by shooting parallel profiles perpendicular to the conjectured strike of the fault. Here again geology helps in determining the possible location and dip and strike of a fault.

Another cause for bad records is found in stratigraphic variations. Assume the velocity of the formation above a reflection contact as v_1 and of the formation below as v_2, now if $v_2 > v_1$ a reflection may be expected but if v_1 or v_2 changes so that $v_1 = v_2$ then the reflection dies out. If $v_1 > v_2$ the reflection is 180° out of phase with the $v_2 > v_1$ reflection. If the reflection follows porosity then the reflection may die out or change character because of stratigraphic variations in porosity.

As shown before, weathering has a great effect on seismogram character and may give rise to areas in which correlation is impossible. In conjunction with this, the shot hole characteristics vary with each subsequent shot, often affecting character to a great extent. Some of the features of seismogram character which are introduced or affected by shot hole variations are:

1. Resonance.
2. Phase change shift.
3. Reflection frequency variations.
4. Ground roll.
5. Dissipation or absorption of energy (amplitude relationships varied).
6. Blastophone.

Several other factors which affect the character of seismogram character but which are more difficult to detect are[35, 36]

1. Explosion impulses do not seem to retain their sudden beginning property or sharp beginnings as they have when leaving the shot.
2. Disturbance from microseisms.
3. Curved geologic interfaces and lenses give rise to distorted wave forms.[16d, 23c]
4. Instrumental
   a. Amplitude distortions as a result of filtering out low frequency rounding of the wave forms and using filters in a wide enough frequency band to eliminate resonance.
   b. Phase distortion which is the result of waves of different frequencies. The velocities are different for different frequencies so that a family of waves from the same reflecting bed may give rise to several initial impulses, out of phase but within a very small time interval, instead of one.
   c. Distortion of compounding records is present when shooting along the dip of the beds as a result of the different arrival angles of the waves.[17]

The character of the seismogram may be expressed mathematically as a Fourier Series by Harmonic Analysis. In this the constants of the equations express implicitly the constants of the recording channels. In experimentation with shaking tables and the use of electrically applied damped wave trains a study of the wave forms of the recording channels is made. If the disturbing wave factors which are introduced in the weathering layer can be eliminated then a closer approximation can be expressed mathematically between the seismogram character and the actual ground motion.[30] It may be that sometime in the future these studies may be refined to a point where it will be possible to use the seismograph as an instrument for investigating stratigraphic traps.

CONCLUSIONS

It can only be repeated that the solution of any problem in correlation entails a background of practical experience and knowledge and a logical application of theory.

It is impossible to completely discuss the art and theory of correlation in one paper because of the large scope of such a field and the secrecy attached to much of the work. With this incompleteness in mind a bibliography has been appended referring to articles which give more detail on certain features only mentioned herein. For example, reference 34 was included as a source of information on seismogram theory, examples of seismograms, and the practical applications of seismic prospecting.

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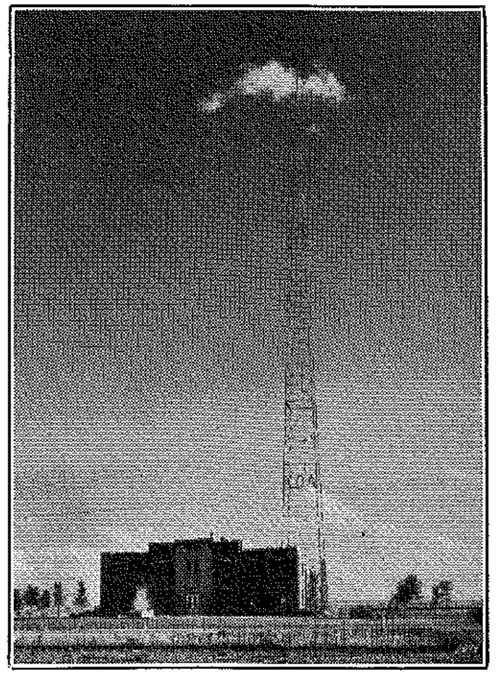
NBC PRESENTS MINES MEN IN "MAN and MINERALS"



Over the Air – KOA – March 31, 1940

GEOPHYSICAL EXPLORATION PART II

Characters
- Dr. C. A. Heiland
- Dr. A. S. Adams
- Coach John Mason
- Operator of Recording Truck
- Voice (on phone)

Sound Effects
- Door opening
- Door closing
- Car running on smooth road (background noise)
- Car running on rough road (background noise)
- Car starting up
- Car coming to stop
- Dull thud of explosion

(*Music:* "Mining Engineer" Fade Behind)

Announcer: The Colorado School of Mines presents "Man and Minerals."

(*Music:* Swells and Fades Into:)

Announcer: Our program takes us to one of the offices in the new Geology-Geophysics Building of the Colorado School of Mines in Golden, Colorado, where we find Dr. A. S. Adams, Dr. C. A. Heiland, and Coach John Mason continuing the discussion of Geophysical Exploration which was started last week. Here they are:

Adams: Say, John, how are you coming with that new invention of yours?

Mason: Was I goin' to invent somethin'?

Adams: Don't tell me you've forgotten already.

Mason: Oh, I remember now—we did have a letter last week from someone wondering about a gadget for finding gold, dollar bills and oil.

Heiland: All right, coach — what about that dollar bill locator you said you were going to invent?

Mason: Now listen, Doc—give me a little more time—I'm not as fast as you geophysical fellows—but say, how do they go about locating these big oil pools underground?

Heiland: Now, hold on there a minute. Oil just doesn't occur like a big pool or lake, or something like that.

Adams: Well, it sort of fills the pores between the mineral grains of sands or sandstones, doesn't it?

Mason: Just like water in a wet sand?

Heiland: Yes. And it may happen that the same sand carries water at one place and oil or gas at another.

Adams: That water, though, is usually salt water and not fresh water. Isn't that right?

Mason: How did it get there?

Heiland: Well, millions of years ago—

Mason: Here we go, folks, the geologists are with us again!

Heiland: Anyway, millions of years ago these sands were deposited in oceans, usually near the shores—

Adams: And in these sands animal and plant remains were buried with the salt water?

Heiland: And out of the organic matter came substances from which oil was formed when more and more sediments were piled up—

Adams: Then you mean these beds were submerged to greater depths where the pressures and temperatures are higher than they are at the ground surface?

Heiland: Right, and often these beds were folded and tilted up.

Mason: Well, Doc, didn't you say a while ago that the same beds may contain salt water at one place and oil at another?

Heiland: Yes, I did. And that separation is the result of the folding and tilting.

Adams: Sure—I see why: the oil is lighter than the water and would tend to go to the highest portions of the sands.

Mason: Is that what they call an oil dome?

Heiland: Yes, in a way, because the oil would be likely to be found near the top of a dome.

Adams: Oh, yes. With your geophysical instruments you'd try to find out where the oil formations come up, closer to the surface?

Heiland: That's what you would try to do in the ideal case—but often we have to be satisfied with indications from other formations that are, in some known way, associated with the oil formation.

Adams: You mean that there may be another bed above or below the oil formation that you can pick up better—say, some bed that might be especially heavy, or—

Heiland: Now hold on there a minute—let me explain first how, by a comparatively simple procedure, we can map underground beds.

Mason: Without being magnetic, or heavy, or something like that?

Heiland: Yes. As a matter of fact, by the use of sound waves.

Mason: Well, that's interesting. How does that work?

Heiland: Dr. Adams will probably remember from his days in the Navy—that they had a device on the ships for measuring the depth to the ocean bottom.

Adams: They called that device a "sonic depth-finder." I suppose that since it worked on the principle of an echo, you could call it an "echo sounder."

Heiland: That's right. Do you remember how it was constructed?

Mason: What's the idea of quizzing him? We are asking the questions!

Adams: Well, they had various kinds of systems, and in one of them, as I recall it, a cartridge was exploded under water on one side of the ship and the echo from the sea bottom was picked up on the other side by a microphone.

Mason: Didn't they have some sort of a meter with it, telling the depth directly?

Adams: Yes, they did. A dial started spinning when the shot was fired and was stopped when the echo hit the microphone.

Heiland: In other words, the device worked on the basis of the time it took the sound to go down to ocean bottom and come back up.

Adams: Yes, indeed, that's the way it worked.

Mason: Now *I* am about to invent something. Why can't you just fire a charge near the ground surface and register the time it takes for the echo to bounce back?

Adams: Just like it is done in the echo-sounder?

Heiland: You really got something there—

Adams: Then, what would you do, just fire a cartridge into the ground?

Heiland: No, we explode a dynamite charge some distance below the surface—

Adams: To get more ground movement out of it, I suppose?

Heiland: That's right. These charges are exploded anywhere between twenty-five to one-hundred-fifty feet deep.

Mason: Well, how do you get the charge down there?

Heiland: By drilling a hole, with a drilling rig, one that's usually mounted on a truck.

Adams: Do you use microphones for detecting the sound, just as they do in the echo-sounders on board ship?

Heiland: Yes, our detecting devices are quite similar. We call them "geophones" instead of microphones.

Adams: Well, then, the dynamite going off represents a miniature earthquake, and the geophones a number of miniature seismographs?

Mason: What's a seismograph?

Heiland: An earthquake-recording instrument such as the one at Regis College. You've seen that word in the papers, its spelled "s-e-i-s-m-o-g-r-a-p-h."

Adams: Is that why they call this geophysical method the "seismic" reflection method?

Heiland: Yes.

Mason: Well, then, how do they register the sound waves, or earthquake waves?

Heiland: Your geophone, or microphone, if you want to call it that, is connected through an amplifier to an electrical recording meter.

Adams: Then that system records the vibrations on a film, just like the sound track is recorded on a movie film, isn't it, Doc?

Heiland: Something like that.

Mason: And when a vibration hits the geophone, you get sort of a wiggle, or kick on the film?

Heiland: Yes, that's right.

Adams: I can see how they record their echoes, but I don't see yet how they get the depth of a reflecting bed from that.

Mason: It seems to me they'd have to record, also, the instant the shot is fired.

Heiland: That's what we do, and from the time that elapses between the firing of the shot and the arrival of the echo, we can then figure the depth.

Mason: Oh, I see.

Heiland: Say, I've got an idea! I thing I'm going to take you fellows for a little ride.

Mason: That's nothing new to me—I get taken for a ride on practically every one of these programs.

Heiland: All right! What I mean is—let's take a ride and visit one of the seismic reflection parties looking for oil structure just a few miles out of Denver.

Mason: That's a good idea. Maybe I'll learn something about this shootin' business yet.

FADE

(Background sound of car traveling while occupants are talking)

Adams: I'm sure glad to get away from the office for a while.

Mason: Gosh, this road is getting rough!

Heiland: Well, they rarely put the geophysicists to work where the going is smooth.

Mason: Well, I don't see a thing but jack rabbits and prairie dogs. Are you sure we're on the right road?

Heiland: Sure, I am.

Adams: Say, do you see that thing over there?

Mason: Oh yes, what is that?

Heiland: It's a rotary drill, mounted on a truck.

Mason: Are they drilling now?

Heiland: Yes. Let's drive up.

(Sound of car coming to a stop)

(Sound of machine running)

Adams: This drill looks like a first-class outfit.

Mason: Look at them going down! —Like going through butter.

(Sound of machine stopping)

Adams: What are they stopping for now?

Heiland: They're ready to come out of the hole.

Adams: That's sure fast work! Look! They're folding the mast. They must be getting ready to move off.

Mason: Where are they going now?

Heiland: They're moving to another location.

Adams: When are they going to shoot the hole they have just drilled?

Heiland: Looks like they're getting ready for that now.

Adams: There's the shooter, putting a charge at the end of a loading pole.

Mason: Let's stay and see the fireworks.

Heiland: You won't see much. They're shooting only about a pound of dynamite and are fifty feet down the hole.

Mason: A pound of dynamite, is that all—

Heiland: Well, it will be a while until they are ready to blow this up. What do you say we drive down the road and see the rest of this party?

(Sound of car starting up)

(Sound of car running during conversation)

Mason: What's that other truck over there for?

Adams: Is that where they keep their recording outfit?

Heiland: Yes.

Mason: Look! There's a man in the road flagging us down to stop.

Adams: What for?

Mason: O-K, O-K, we're stopping.

(Sound of car coming to a stop)

Heiland: See those wires coming out of the recording truck? They're hooked to their geophones—

Adams: Are those the things that look like tin cans and barely stick out of the ground?

Heiland: Yes, and they are picking up the ground vibrations produced by our car.

Adams: Is that why they wanted us to stop?

Mason: Yes, but it's hard to believe that they can detect us at this distance.

Adams: This must be a very sensitive outfit!

Heiland: Yes, it magnifies the ground motion several million times.

Mason: Look, they're motioning us to come on.
(Sound of car starting)
Adams: Let's drive over to the recording truck.
(Sound of car running)
Mason: Well, they've got more equipment here than Carter has pills.
Adams: Ad lib.
(Sound of car stopping)
Heiland: Here we are. I guess the operator is inside his truck. Let's wait until he comes out.
(Sound of door opening)
Operator: Hello, there, fellows!
Mason, Adams: Ad lib.
Heiland: Hello, Tom! I would have sworn I saw you on the street in Denver the other day. Didn't know you were working with this seismic crew out here.
Operator: Yep, shootin' this country full of holes. (pause)—Guess I have to get back inside. They're about ready to shoot.
Mason: What's he doing now?
Heiland: He's turning on his amplifiers.
Operator: (Inside truck) — About ready?
Mason: Who's he talking to?
Heiland: The fellow at the shot point—got a phone wire running over there.
Adams: Then, he's the one that gives the order to shoot?
Heiland: Yes. Let's be quiet. They're about ready.
Operator: (Inside truck) Ready?
Shooter: (Voice on phone) Ready!
Operator: Contact!
Shooter: (Voice on phone) Contact!
Operator: Shoot!
(Sound, dull thud)
Mason: That wasn't much of an explosion.
Adams: What's the fellow in the truck doing now?
Heiland: He's developing his film.
Mason: This thing was sure all over with in a hurry.
Heiland: Their first reflection here comes from a bed four thousand feet deep and is recorded one second after the shot is fired.
(Sound of door opening)
Operator: (Steps out of truck) Want to look at a record?
Mason, Adams: Sure do!
Adams: Are these wiggly lines the records of your geophones?
Operator: Yes. And here, where all the kicks show at the same time, we have a reflection from about a four thousand foot depth, one from six thousand, and one from an eight thousand foot depth.
Heiland: We've got to get back to town. Thanks very much, Tom. We'll be seeing you.
Adams, Mason: Ad lib.
(Sound of car starting)
(Sound of car running during conversation)
Mason: This looks to me like shooting fish in a rain barrel.
Adams: With a lot of complicated fishing equipment, though.
Mason: I can see where it would cost quite a few thousand dollars per month to keep one of these parties going.
Adams: Tell me, how accurately can they map these formations below the surface?
Heiland: Oh, with an accuracy of about five feet for every thousand feet of depth.
FADE
Adams: Well, that sure was an interesting trip.
Mason: I should say so. You know, I've been thinking about something —you know what I mean—that gadget I couldn't pronounce last week—
Adams: You mean the "gravimeter," John?
Mason: Yes, that was it.
Adams: Didn't you say that was used a good deal in geophysical oil exploration now?
Heiland: Yes, it is. You had the right idea about that. Remember what you said about that before we went out on our trip?
Adams: Oh yes, I guess I did say that it should be possible to find geologic formations when one is heavier than the other.
Heiland: Well, usually formations become heavier with depth. Therefore, when a series of beds is pushed up, the lower and heavier formations are closer to the ground surface than they are at the sides of the dome.
Adams: And, therefore, the gravity pull is greater over the dome?
Mason: You mean it pulls down the weight of the gravimeter more there than at any other place?
Heiland: Yes, it does.
Adams: Well, then, is it as easy to figure out the depth of formations from that gravimeter reading as it is from reflection shooting?
Heiland: No, it isn't.
Mason: Well, then, what's the advantage of the gravimeter over the shooting?
Heiland: The gravimeter is quite a bit faster and less expensive to operate.
Mason: I don't want to change the subject, but I still keep thinking about our Swedes and their simple magnetic method of locating iron that you talked about last week.
Adams: Yes, how about that? Can't that method be used somehow in oil exploration?
Heiland: Yes, it can—and it has been used.
Mason: How's that?
Heiland: Let's use a simple example. Take these mountains—
Mason: The ones we can see right out of our window?
Heiland: Yes. And let's assume that in the course of millions of years, these mountains are covered by the sea again.
Mason: You mean the mountains would just lower themselves and allow the sea to cover them?
Adams: Then the beds laid down in the sea would fill up the depressions between the mountain peaks and eventually bury them?
Heiland: Yes, they would, and the buried mountains would then provide a trap for the oil that might develop in those beds from animal remains!
Adams: I see, and if the sea receded you would find these mountains buried under thousands of feet of sediment, wouldn't you?
Mason: Well, I don't see yet where a magnetic method would help you to locate buried mountains.
Heiland: Well, the answer is fairly simple in that case. These mountains are made up of rocks that contain iron minerals.
Mason: Well then, it's the same thing we talked about last week. You could then indirectly locate structure favorable for the occurrence of oil by trying to find such old buried mountains.
Adams: You sure have a great variety of methods then. I suppose the one you use depends on the geologic conditions, doesn't it?
Heiland: Yes, it does.
Mason: But what I'd like to know is just what has been accomplished with all this?
Heiland: Well, one thing is certain. Geophysics has reduced the cost of oil-finding materially.
Adams: How much?
Heiland: To use the words of one of the prominent operators: "In the early twenties, the average cost of finding oil was twenty to twenty-five cents per barrel."
Mason: And how much has it been reduced since the introduction of geophysical methods?
Heiland: Since then, the cost of oil-finding has gone down to ten or twelve cents per barrel.
Mason: A reduction of 50% isn't to be laughed off by anybody.
Adams: Has anybody ever tried to estimate the amount of oil found by geophysics?
Heiland: Yes, it has been estimated that over five billion barrels had been found by 1939.

(Continued on page 458)

ELIMINATION OF DANGEROUS PEROXIDES IN ETHERS

By
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Associate Professor, Chemistry
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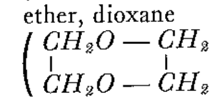
Introduction

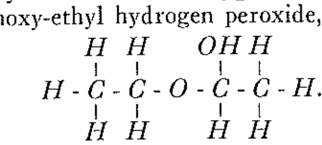
As a result of an explosion which occurred in the Organic Chemistry Laboratories of the Colorado School of Mines, while isopropyl ether was being distilled on a steam cone late in the fall of 1938, a study of ethers and their explosive peroxides was undertaken. This study was started in November 1938 in the hope that a way might be found to prevent the formation of peroxides, or that a method of treating peroxidic ethers might be developed which would be fast and easy. The purification of ethers is a problem which the modern petroleum refiner faces. Since ethers, especially isopropyl ether, are made as by-products of the cracking stills, their preservation is an economic problem to the refiner.

Occurrence of Peroxides in Ether

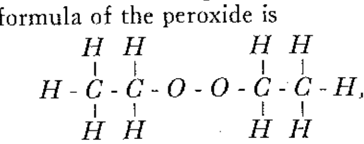
Ethers, of which diethyl ether is by far the best known because of its anesthetic properties, are a group of hydrocarbon derivatives consisting of two hydrocarbon radicals connected to one oxygen. Their general formula is ROR', where R and R' consist of hydrocarbon radicals. The ethers studied were diethyl $(C_2H_5OC_2H_5)$, diisopropyl $(C_3H_7OC_3H_7)$, diisoamyl $(C_5H_{11}OC_5H_{11})$, and a cyclic di-ether, dioxane



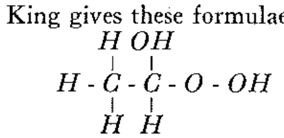
The actual mechanism of the peroxidation of the ethers is not clearly understood. A. M. Clover[1] in 1922 published a paper on the autoxidation of ethers in which he postulated that ethyl ether takes on oxygen to form α ethoxy-ethyl hydrogen peroxide,



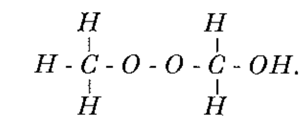
Wieland and Wingler[2] state that the formula of the peroxide is



and King gives these formulae:



and



The three main theories for the formation of peroxides are the Engler-Bach theory, the dehydrogenation theory, and the electronic theory.

Engler and Wild,[4] Bach,[5] and Baeyer and Villiger[6] set forth the simplest explanation for the peroxidation of ethers. Their theory is that the oxygen atom in the ether attracts molecular oxygen and that this molecular oxygen adds to the ether oxygen atom with a ratio of one molecule of ether adding one molecule of oxygen.

Wieland and Wingler[2] state that since this theory does not account for the autoxidation of alcohols, thioalcohols, hydrazine, and others, it is not the true autoxidation mechanism. They give as an explanation a dehydrogenation theory, that is, that the ether first loses hydrogen and then forms the peroxide.

Milas[7] shows that the Engler-Bach theory works in many cases, but it does not explain catalysis and chain mechanism, while the dehydrogenation theory is claimed by Milas to explain only a few reactions, where it is a secondary reaction. He gives as an explanation of autoxidation, the electronic theory. This consists of the addition of molecular oxygen to ether forming "dative peroxides" which are highly unstable and give off energy while changing to the ordinary peroxide. This energy is then used to start a new chain of reactions.

It is not the purpose of this study to prove or disprove any of these theories. They merely show possible ways by which these peroxides are formed. An understanding of any of these theories, however, helps to explain some of the reactions of ether and oxygen.

The products, both primary and secondary, of the autoxidation of ethyl ether have been fairly well agreed upon. A. M. Clover[1] gives the following: Acetic acid, ethyl alcohol, hydrogen peroxide, carbon dioxide, methane, and acetaldehyde. Nearly all authors give acetaldehyde and hydrogen peroxide as the main by-products.

Effect of Peroxides in Ethers

Since ethers, especially ethyl ether, have been used both for medical and chemical uses, the effects of peroxide contaminants in them are widely different. The universal use of ether as an anesthetic makes the production and preservation of pure ethyl ether a problem. Many articles have been published about the effects of contaminants in ether on the human system. The two main objectionable impurities in ether from the medical standpoint are aldehydes and peroxides. Since both of these are products of autoxidation of ether, they are of interest here. Mendenhall and Connolly[8] state that small amounts of aldehyde or peroxide bring about distinctly toxic effects on the ciliary action, (the action of the eyeball), while pure ether is not poisonous. Nolle[9] states that the aldehydes in ether have no effect on the heart muscle unless accompanied by peroxides. Since from the work of Clover[1] it has been shown that aldehydes catalyze the formation of peroxides, the aldehydes would in all probability be accompanied by peroxides. Coste and Garratt[10] say that although ether should be pure, peroxides themselves are not the cause of the after-effects produced by impure ether. While some of these statements conflict, all of these men and women agree that the best ether for anesthesia is one which is pure. Therefore any method of removing peroxides and aldehydes is useful.

The biological effects of impure ethers are usually a matter of discomfort to the patient and are not as serious as the explosions which may occur when ether is distilled. These explosions occur when peroxidic ether is distilled and the unstable peroxides concentrate in the residue. Paul Arup[11] states that the residue from distilling methylated ether explodes at 124°C. While distilling isopropyl ether on a steam bath, we had an explosion at a temperature of less than 100°C. The ether was being distilled in a liter Claisson flask and the explosion blew the corks out of both necks, throwing the thermometer against the ceiling, a distance of about

Presented at Engineers' Day, Colorado School of Mines, March 15, 1940.

12 feet. Since all the sample had been distilled, no determination could be made on the peroxide content of the original sample.

The force of the explosion of ether peroxides was demonstrated by Morgan & Pickard.[12] They stated that one worker was nearly blinded when an explosion occurred while distilling isopropyl ether. Another explosion occurred later and the workman was saved from the flying glass because of the safety glasses he wore. They tested the ether by evaporating 4 grams of isopropyl ether in a cylindrical cavity in a thick steel disc. A loosely fitting cylinder was placed in the cavity above the residue and a 1¾ pound weight was dropped on the cylinder from a height of 1 ft. An explosion occurred from the shock which threw the weight 8 ft. in the air, where it put a ¼" dent in a 20 gage steel screen.

Since ethers are used as solvents and are usually distilled from the dissolved material, the presence of peroxides which may explode with such force is very dangerous. Arup[11] states that purified pentabromacetone decomposed peaceably with heating, but that which had been separated with "Methylated Ether" exploded, showing the danger of distilling impure ether extractions. He states that flying glass from such explosions has cleanly punctured thick walled glass vessels, showing that these explosions throw glass in all directions with speeds higher than that of bullets. One of the most unique accidents from ethers was one which was reported in England.[14] An explosion occurred while hot air was being passed into the mouth of a dentist's patient on whom ether had been used as an anesthetic, killing him instantly.

Another possible effect of peroxides in ethers is the fact that the peroxides may cause side reactions during ether extractions, thus lowering the yields of many syntheses.

Methods of Preventing or Destroying Peroxides

Many methods are given in the literature for preventing the formation of peroxides in ethers. MacCulloch[15] states that a 20 gage copper wire placed in the ether prevents peroxide formation. Similarly Joseph Rosin[16] has patented a method of preventing peroxide formation in which he placed a bundle of iron wire in the ether can. Another method is the addition to the ether of oxidation inhibitors such as diphenylamine, alpha napthol, hydroquinone, and other common inhibitors used for preventing gum formation in gasolines.[13] However these contaminate the ether, and care must be taken in choosing an inhibitor that it does not interfere with the purpose for which the ether is to be used. Of the methods previously reported of purifying ethers, the distillation of the ether over sodium hydroxide *(NaOH)* is probably the easiest and fastest.[17] Other methods consist of passing the ether through oxides of lead, copper, manganese, and other metals, in the vapor phase.[18] This is not very easily done however because of equipment needed. Another method is to add an aqueous solution of ferrous sulfate *($FeSO_4$)* to the ether, shake, and separate the ether.[19]

The *NaOH* method is also good for removing aldehydes thru the Cannizaro reaction according to Tonn.[20]

Results of Experiments at the Colorado School of Mines

The time and trouble encountered in treating the ethers with *NaOH* solution, in which method a distillation is necessary, brought about a study of other methods which might be used for removing peroxides more easily. Moreover dioxane cannot be purified by either of the above methods. It boils at nearly the same temperature as water (105°C.) and cannot be distilled from water. Therefore the sodium hydroxide method is not possible. Also, dioxane is soluble in water and cannot be separated as is needed in the ferrous sulfate method.

Peroxides are unstable and are both oxidizable and reducible, analagous to hydrogen peroxide, therefore, the first things tried were solid reducing agents such as sodium bisulfite, ferrous sulfate, powdered zinc, and stannous chloride. Of these, the stannous chloride was the only one to affect the peroxide content. After shaking with stannous chlorine, contaminated dioxane containing *.108N* peroxide gave a negative test for peroxides. However the stannous chloride is very soluble in dioxane and therefore dioxane must be distilled off to eliminate the stannous chloride.

Suggestions by Yoshio Konishi[18] and Demougin and Landon[21] that metals and metal salts act as catalysts, either negative or positive, led to a study of the effects of metals and their salts on ethers. Pure isopropyl ether and pure ethyl ether were put in 2 oz. bottles with various metals for 5 months. At the end of this time the amount of peroxide that each ether had developed was determined in terms of equivalent hydrogen peroxide by the following methods:

To 10 cc. ether and a few crystals of manganous sulfate in 50 cc. of normal sulfuric acid, add one tenth normal potassium permanganate solution until the pink color produced by 2 drops of permanganate has not entirely faded in 10 sec.[3] This method was checked by the usual iodine method as follows: To 150 cc. of twice normal sulfuric acid and 10 cc. of ether, add 3 to 5 drops of 1% ammonium molybdate solution followed by 15 cc. of 10% potassium iodide solution. After shaking thoroughly and allowing to stand for 15 minutes, titrate the liberated iodine with *0.05N* sodium thiosulfate shaking well after each addition of reagent.[22]

The results of this experiment agreed with those of many other experimenters. The blank sample of ethyl ether developed a normality of *.005N*. Liversedge[23] states that light catalyzes the oxidation, and one sample which had been kept in the dark only developed *.001N* as compared to *.005N* of the blank which had been in the light. Another sample, contaminated with aldehyde, developed the highest normality of peroxide *(.01N)* agreeing with Clover.[1] MacCulloch stated that copper prevented peroxide formation and a sample with copper wire in it remained at a very low normality *(.0005N)*. However the sample with iron wire in it developed *.005N* disagreeing with Rosin. Sodium kept the peroxide content to *.0005N*. However sodium is not easy to handle in ether. The most noticeable and startling result was that the lead oxides, PbO_2 and Pb_3O_4 prevented the peroxidation and gave a normality of *.0002N*.

On isopropyl ether the sodium acted the same as on the ethyl ether, keeping the peroxide to a minimum. However copper allowed a normality of *.008N* to develop. Although this was half of the blank *(.016N)*, it shows that the copper is not dependable. PbO_2 and Pb_3O_4 also kept the peroxidation of the isopropyl ether to a minimum *(.0005N)*.

The discovery that PbO_2 and Pb_3O_4 destroy peroxides led to a series of confirmatory experiments on lead dioxide. The action of these compounds on the peroxides is explained as a reaction in which the lead compounds oxidize the peroxides, while the lead is being reduced to the lower valence. A sample of isopropyl ether containing *.025N* peroxide was shaken with PbO_2 for 5 minute intervals, filtering through a tight filter paper, Munktell #00, and titrated. On successive shakings the normalities of peroxide in the ether steadily dropped to *.0015N* after 5 shakings. Since PbO_2 is insoluble, and lead acetate, the most probable product, is insoluble in ether according to Storer, the presence of lead in the filtered ether was not expected. It was found that a small amount of lead dioxide remained in suspension if a loose filter paper was used, but if a fine paper is used no lead can be detected with hydrogen sulfide by extracting the residue from the distilled ether with

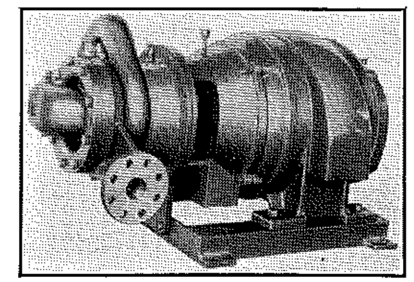
(Continued on page 465)

WITH THE *Manufacturers*

EQUIPMENT NEWS

Multi-Stage Unit Pumps

Allis-Chalmers Mfg. Company, Milwaukee, Wisconsin, has recently extended its line of multi-stage "SSUnit" pumps in which the motor and pump housings are bolted together for compactness. This includes a new two stage pump with 4 inch suction and 2 inch discharge that can be rated up to 275 gallons per minute against heads up to 500 feet at a speed of 3550 rpm.



The new pump, like the company's smaller multi-stage pumps of this type, has cast iron casing and cover, and is bronze fitted throughout. The impellers are placed back to back to provide axial balance. The cover can be readily taken off, permitting the inside parts to be removed without disconnecting the suction and discharge piping. The stuffing box on the pump is only subjected to suction pressure.

This unit can be furnished with either an open, splash-proof, totally enclosed or explosion-proof motor. It is suitable as a small boiler feed pump, mine pump, or pipe line pump. It can be used in humidifier work, air conditioning service, oil loading and many other small capacity, high pressure services. Bulletin B-6105 will be sent on request.

Safety Goggles for Gauges

Safety is the most important of several features of the new Durafront or plastic gauge cover recently developed by the Ashcroft Gauge Division of Manning, Maxwell & Moore, Inc., Bridgeport, Connecticut. The makers claim that these new plastic Durafronts (which replace the old-fashioned gauge glasses) actually "put safety goggles on gauges so that operators don't have to wear them."

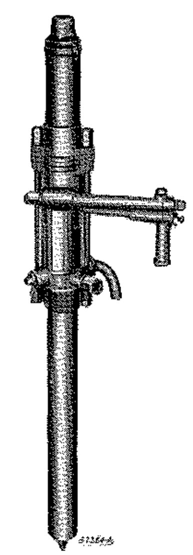
It is stated by the manufacturers that these plastic Durafronts are of particular interest to all industrial plant Safety Engineers because they eliminate *all* possibilities of workers being injured by broken or flying gauge glass. This safety feature is also proving of great interest to all major workmen's compensation insurance companies. So much so in fact, that they have distributed descriptive literature to hundreds of their field men who are recommending the use of Ashcroft Durafronts as an added safety precaution for their clients.

These Durafronts for gauges are molded of crystal-clear plastic with a tensile strength of 5,000 pounds and a

compression strength of 15,000 pounds. The makers further claim that these new gauge Durafronts increase the visibility or readability of gauges and at the same time give them a modern, streamlined appearance that greatly adds to the beauty of gauge board installations.

Ashcroft Durafronts are optional on Duragauges at no extra cost. They are available in 3½", 4½" and 6" sizes and can be added to any plastic (phenol case) gauge now in service. Descriptive literature may be had by writing to the makers.

New Stopehamer



▼The New Ingersoll-Rand R-58 Stopehamer.

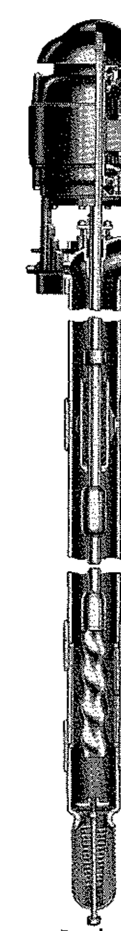
Ingersoll-Rand has just announced a new 116 pound "Balanced for Easy Handling" Stopehamer with automatic rotation, known as the R-58. The center of gravity of this Stopehamer is such that the machine assumes a natural drilling position when it is picked up. This facilitates raising the machine to any operating position.

Other "Ease of Handling" features include: feed-leg control which permits many fine variations in feeding power; short over-all height of only 59 inches prevents the drill from being top-heavy; a plate-type throttle valve provides half throttle position for "collaring" holes; and the location of the exhaust on the opposite side of the cylinder from the operating controls.

One of the many durability features of this Stopehamer is an automatic chuck cleaning system which keeps the drill free from cuttings and water and at the same time provides ample lubrication for all fronthead-bearing surfaces.

An eight-page illustrated booklet, including a disassembled view is available from Ingersoll-Rand Company, 11 Broadway, N. Y., or any of its branch offices. Send for Form 2647.

Peerless Hi-Lift Pump



▼Peerless Hi-Lift Pump Showing Unique Helical Rotor and Chromium Armored Bearing.

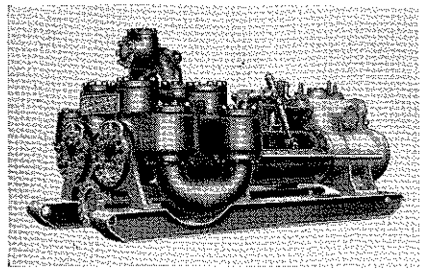
By heavy application of electrolytically-deposited chromium over a monel stainless sleeve which has been swedged into a vertical pump shaft, a new type of water-lubricated bearing has been produced by Peerless Pump Company of Los Angeles. The process has been perfected for use in deep well vertical pumps. The pump shaft is armored with heavy chromium over a non-corrosive metal sleeve every ten feet. These sections of the shaft operate within resilient cutless rubber journals, which are fluted and are non-revolvable. Any sand in the water flushes through the bearing. Because of the extreme hardness and thickness of the chrome, and its bearing contact with cutless rubber, no abrasion occurs, according to Peerless engineers. Heretofore the use of a chrome surface was not satisfactory, due to its microscopic porosity, its thin wall and its eventual disruption from the carbon steel to which it was usually bonded. By the new Peerless process the chromium is electrolytically deposited to monel to a thickness of approximately three thousandths of an inch, which is more than fifty times as thick as ordinary automotive chromium plating and several times the thickness of chrome heretofore applied. In pumps placed under accelerated life tests, pumping water heavily laden with sand, the results indicate a shaft life of twenty-seven times that of an ordinary carbon steel shaft.

A bulletin describing this new chromium-armored bearing may be obtained by writing to Peerless Pump Company, 301 W. Ave. 26, Los Angeles.

New Slush Pump

The Gardner-Denver Company, Quincy, Illinois, has recently placed on the market a new line of 20" steam slush pumps which are mounted on steel skids which make the unit easily moved.

A new alloy iron known as "GarDurloy" for hydraulic cylinder service has been developed by the Gardner-Denver engineers and metallurgists which is now standard in these slush pumps. This alloy has a greater uniform hardi-



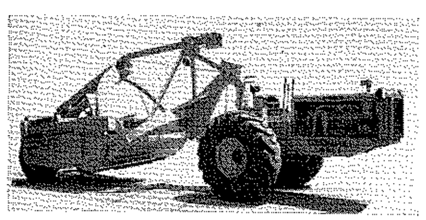
ness and greater erosive action resistance than either gray iron or cast steel. An outstanding feature is the divided fluid cylinder construction, this end of the pump consisting of two entirely separate castings. The greatly enlarged passages in the improved suction manifold reduces shocks and friction, thus making a smoother running pump. The roller bearing steam valve motion is another improvement found on this pump.

So that you may appreciate the many valuable features incorporated in the construction of this pump, which make for efficient operation, the manufacturers invite you to write for Bulletin P-234, Sixth Edition, and they will be glad to furnish additional data and information.

Small Tournapull Introduced

Combining the speed of a truck and the power of a tractor with a capacity for the average job and Scraper self-loading and self-spreading economy, R. G. LeTourneau, Inc., Peoria, Ill., world's largest manufacturer of tractor-drawn earthmoving equipment has developed its third and smallest Tournapull, known as the Model C, for long haul dirt moving.

Powered by a "Caterpillar" four cycle, six cylinder D-468 Diesel engine, it has a top speed of 13 to 15 miles per hour, depending upon tire equipment. At 1800 rpm it develops a maximum brake horsepower of 90.



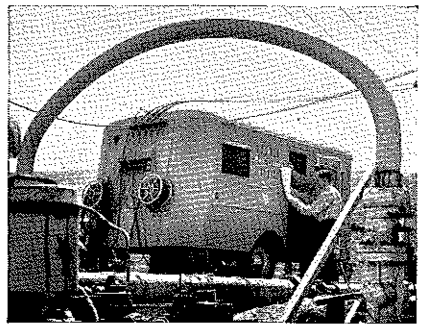
Mated to the Model C Tournapull is the newest and one of the most popular Carryall Scrapers, the Model LS, with a struck capacity of 8.2 cubic yards and a heaped of 11. The latest features introduced by LeTourneau such as the crescent arch "A" frame, larger apron and traveling sheaves controlling apron are all incorporated in this Carryall.

The Tournapull and Carryall combination is a self-loading unit. However, to get the maximum operating efficiency, reduced loading time and increased pay yards pusher loading is recommended.

Tournapull speeds compare very favorably with those of large trucks. In addition, Tournapulls are able to negotiate adverse ground conditions that are impossible for road-bound trucks even of four-wheel design. Being a self-loading and self-spreading unit, the economies of tractorscraper operation are extended to truck haul jobs and, as a result, longer and more difficult hauls made faster and cheaper. Dirt costs on the long haul can now be commensurate with that obtained by Scraper operation on short hauls.

Well Logging Service

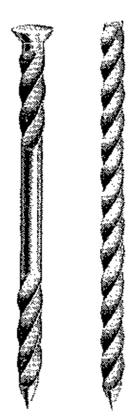
The Baroid Well Logging Service has attracted widespread attention because of its entirely different basic theory and the fact that continuous well logging is accomplished right at the time of drilling and without interruption of drilling operations.



In drilling a well, the bit drills up and disintegrates a circular core of the formation being drilled. If gas, oil or salt water are contained in the pore spaces of this core when it is drilled, the content of the pore spaces must of necessity be picked up by the drilling fluid. If the drilling fluid is continuously analyzed upon its return to the surface and correlated with the depth from which the cuttings came, the gas, oil or salt water content of the formation can be accurately determined.

Literature illustrating and describing the Baroid Well Logging Service is available from the Baroid Sales Division, National Lead Company, at Los Angeles, Houston and Tulsa.

A New Double Grip Spike and Giant Grip Dowel



The Gary Screw and Bolt Company, Chicago, announces a new Double Grip Spike and a new Giant Grip Dowel. The Double Grip Spike represents one of the greatest advances in timber fabrication in recent years. The blank mid-section has been introduced to facilitate both driving and removal. Their use gives a permanency to all wooden structures, such as bridge decks, platforms, crossings, etc., that is much to be desired; and a complete elimination of maintenance can be effected. The spike turns as it is driven, thus cutting its own thread in the wood, and under stress it acts as right and left hand threads, giving remarkable holding power.

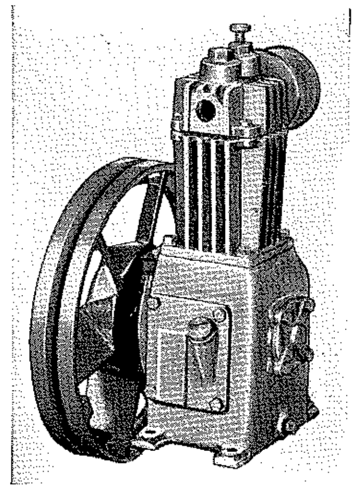
The Giant Grip Dowel is essentially a twisted steel pin with spirally grooved ridges in its entire length. The lead of the spiral thread is sufficient to permit driving by any suitable means, either mechanical or manual. The dowels are highly effective in redeeming and salvaging badly split timber, such as ties, bridge caps and stringers, and timber generally.

The Double Grip Spike and the Giant Grip Dowel are stocked in this territory by THE MINE AND SMELTER SUPPLY COMPANY, DENVER.

News Release on New Equipment
From Sullivan Machinery Company, Michigan City, Ind.

New Line of Small Air Compressors

Supplementing its line of Portable and Stationary air compressors, the Sullivan Machinery Company is now offering a group of compressor units in smaller sizes. The new line, known as Type "Q," is applicable for industrial, garage and diesel starting service. The units are air cooled—single and two stage—and range in capacity from 2.8 to 45.7 C.F.M.,—½ to 10 H.P., with operating pressures (continuous) 100—200 lbs. and (intermittent) 150—500 lbs. The smallest unit is 10⅛x14x18 inches high . . . the largest 20¾x19½x25⅞ high.



These "Q" compressors have cushioned air valves, balanced crankshaft, taper roller main bearings, Lynite connecting rods, semi-steel pistons, positive lubrication, copper intercooler, chrome nickel cylinders and dust-proof crankcase. Automatic starting can be furnished.

Units are available bare, base mounted or tank mounted, for V-belt drive from motor or air cooled gasoline engine. Units for diesel starting may have combination motor and gasoline drive, so arranged that the belt can readily be shifted to the gasoline engine in case of current failure.

Write for Bulletin A-33—Sullivan Machinery Company, Michigan City, Indiana.

"Chrome Face," The New Steel Tape

"Chrome Face" is the name of the line of Steel Measuring Tapes that has just been put on the market by The Lufkin Rule Company. These Tapes are entirely new and different than any others. Their markings are durable as well as easy to read. These are their outstanding characteristics and these two features are most important to every user of Tapes.

They are accurate Steel Tapes, chrome plated, with jet black markings and satin chrome-white surface, unusually free of glare. Hence, the permanent markings stand out in sharp contrast, showing up well even in poor or artificial light. Furthermore, being built up by chrome plating these Tapes are extra strong and resist rust. The surface is smooth, hard and easy to clean, and the Tape, being of metal throughout, will not crack, chip or peel. New cases and frames of improved design and appearance have been built for this new line.

As a Tank Gaging Tape the Chrome Face Line will appeal most strongly to the oil industry for two principal reasons: On its dull chrome-white surface the oil

(Continued on page 459)

CATALOGS AND TRADE PUBLICATIONS

FOR YOUR CONVENIENCE

Send your publications to Mines Magazine, 734 Cooper Building, Denver, for review in these columns. Readers will please mention Mines Magazine when requesting publications from the manufacturer. Readers may order publications from this office by giving index number.

(1031) FLEXIBLE COUPLINGS. Catalog No. 1845 by the Link-Belt Company, 307 North Michigan Avenue, Chicago, Illinois, on the company's complete line of flexible couplings with revolving and stationary casings. Illustrations, horsepower ratings, secifications, design examples, correct service factors and proper lubrication and alignment instructions are given.

(1032) PENNSYLVANIA TURNPIKE. "Industrial News" by the Gates Rubber Company, Denver, Colorado, July, 1940, gives pictures and discussion on America's first Super Highway. 160 ft. road from Harrisburg to Pittsburgh with no grade crossings and eleven interchanges for entering or leaving the road. Road completed in 20 months including 20 miles of tunnel. Self-liquidating in 14 years.

(1033) TERMINATING TELLURIUM CABLE. Bulletins GEA-3361 and 3362 by General Electric Co., Schenectady, N. Y. Complete instructions with dimensioned illustrations showing how to terminate tellurium parkway shielded, single-conductor cable and braided, shielded single conductor cable.

(1034) CORK INSULATION. July issue of Armstrong Cork Company, Lancastar, Pa., monthly bulletin. Pictures and stories on how packing houses, ships, frozen food companies, ice companies, dairies, etc., use cork insulation to keep their products cool.

(1035) METAL MINE LOCOMOTIVES. Bulletin H-320 by Goodman Mfg. Co., Halstead St. at Forty-Eighth, Chicago, Illinois. Discussion on storage battery, trolley and combination battery and trolley locomotives supplemented with pictures of Goodman locomotives furnished for various mining companies.

(1036) AIR COMPRESSORS. Bulletin H620-B22 by Worthington Pump and Machinery Corporation, Harrison, New Jersey. Illustrations and specifications on type VA and VA2 machines. These units are two cylinder, air cooled, 4 inch stroke compressors available in either single or two stage units.

(1037) AIR CIRCUIT BREAKERS. 16 page booklet B-2243 by Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pennsylvania covering their entire line of air and compressed air circuit breakers from 15 amp. to 1,500,000 KVA capacity. It gives a short history of the development of the air circuit breaker including the development of the "De-Ion" process. Photographs of typical installations and circuit diagrams for various applications are included.

(1038) OIL WELL EQUIPMENT INDEX. National Supply Co., Toledo, Ohio. Descriptive bulletin index. This index alphabetically lists all of the descriptive bulletins issued by the National Supply Co.

(1039) MOLYBDENUM STEELS. June 1940 issue of the "Moly Matrix" published by the Climax Molybdenum Co., 500 Fifth Ave., New York. Interesting discussion on the advantages of Carbon-Molybdenum steels for locomotive boiler service. Also a story on a Nickel-Chrome-Molybdenum valve that has had 13 years service at the base of a sulfuric acid storage tank.

(1040) ROTARY PUMPS. Bulletin W-475-B14 by Worthington Pump and Machinery Corp., Harrison, New Jersey, on their type Gl small capacity, low pressure rotary pumps. Gives special features, applications, specifications, dimensions and a table showing typical speeds, capacities, pressures and power requirements.

(1041) COMPRESSORS. Supplement B to Bulletin No. 726 by Chicago Pneumatic Tool Co., New York, on horizontal tandem duplex motor-driven compressors. Sectional cut shows details of operation with explanatory notes describing the different parts of the machine. Pictures of actual installations are included.

(1042) BELT CONVEYOR. Bulletin No. C-373 by Goodman Manufacturing Co., Chicago, Ill., describes their 97 belt conveyor designed to handle coal, rock and slate in mines which have uneven bottom and close posting. A lightweight, reversible, troughed belt conveyor motor driven through a speed reducer, flexible coupling and a chain and sprocket connection to the drive pulleys.

(1043) GAS ENGINES. Bulletin No. 268 by the National Supply Co., Toledo, Ohio, on type CM 2 cycle horizontal, convertible Superior gas engines. A slow speed, heavy duty engine designed for pumping service where less than 25 H.P. is required. Descriptive material and illustrations are supplemented by a specification table and horsepower curves.

(1044) DIESEL SWITCH ENGINES. Bulletin GED 803 by General Electric, Schenectady, New York. Descriptive and cost data on diesel electric locomotives recommending replacement of old steam locomotives for switching service. Several pages of illustrations showing diesel-electric switchers in actual service.

(1045) MAUREX ELECTRODES. Mine and Smelter Supply Co., Denver, Colorado is distributing a wall chart of Maurex electrodes showing use, identification and average current values in amperes on 16 different electrodes. Also is included a chart of competing electrodes showing types made by other electrode manufacturers.

(1046) STATIONERY SUPPLIES. Catalog by Kendrick-Bellamy Company, 801 Sixteenth St., Denver, Colo., showing their line of stationery and office supplies for the office, warehouse, factory and home. Price list No. 3 supplements this catalog.

(1047) COAL WASHING TABLE. Bulletin No. 119 by Deister Concentrator Company, Ft. Wayne, Indiana, describes their No. 7 coal washing table. Cleans either bituminous or anthracite coal in sizes up to 1½". Diagonal deck operated by a 3 H.P. motor for starting and operates at substantially 1 H.P. under continuous operation.

(1048) INSULATED CABLE. Bulletin GEA-2733D, General Electric Company, Schenectady, New York tells about "Flamenol" a synthetic-insulated wire with the single covering that serves the dual purpose of an insulation and a finish. "Flamenol" has high dielectric strength, it is tough and strong needing no protective lead, or armor except where mechanical abuse is extremely severe. It is practically ageless, flame-resisting, and is not attacked by oils or solvents, nor by acids and alkalies.

(1049) NICKEL ALLOY CASTINGS. Their use on various types of equipment, including two 25-foot diameter double drum mine hoists built for installation at the Homestake Gold Mine, Lead, South Dakota, is described in the July issue of Nickel Cast Iron News published by the International Nickel Company, 67 Wall Street, New York, N. Y. Interesting pictures showing longer life obtained by using nickel cast iron parts than from ordinary non-alloy parts are included.

(1050) SCREW CLASSIFIERS. Bulletin No. S. C. 640, Western Machinery Co., 760 Folsom St., San Francisco, California, gives types, drawings, photographs and lists mechanical and operating advantages of their screw classifiers. They feature the special alloy removable shoes and the motor driven screw lifting mechanism on their machines.

(1051) ASSAY LABORATORY SUPPLIES. Catalog No. 104, published by the Mine & Smelter Supply Co., Denver, Colorado, lists their complete stock of supplies and equipment for the assay laboratory. Prices are included in the catalog.

(1052) LOAD LIFTER HOISTS. Bulletin No. 347, by Shaw-Box Crane & Hoist Division of Manning, Maxwell & Moore, Muskegon, Michigan, describes their electric hoists from 350 to 1000 pounds capacity. These hoists are simple to operate either by pendent cords or push buttons. They are light enough to move from job to job, have a rapid rate of lift and will lift loads a maximum of 18 feet off the ground. A page of specifications is included in the bulletin.

(1053) DIRECT CURRENT MOTORS. Forty page bulletin B6002, by Allis-Chalmers, Milwaukee, Wisconsin, shows a large number of installation views of heavy duty motors in operation and devotes many pages to the design features of these machines. It also includes a section on switchboards and control for use with such large rotating equipment. Application to the steel and mining industries is stressed.

(1054) CENTRIFUGAL PUMPS. Bulletin A-105, by the Gardner-Denver Company, Quincy, Illinois, describes their horizontally split case, centrifugal pumps, types D, E, F, G, and GA for heads up to 300 feet. A description of each part of the pumps is given and pictures of operating installations are shown.

(1055) MANGANESE STEEL. July 1940 issue of the Amsco bulletin, published by American Brake Shoe & Foundry Company, Chicago Heights, Illinois, contains 22 pages of descriptive material and pictures telling and showing how manganese alloys and welding rod give increased life to the fastest wearing parts of various types of industrial equipment.

(1056) DIESEL ENGINES. Form 6056, entitled "On The Job" by the Caterpillar Tractor Company, Peoria, Illinois, contains photographs and discussions on more than a hundred typical installations of Caterpillar diesel engines. Twenty specific classifications, and dozens of miscellaneous installations are photographed and discussed to give a broad outline of the general adaptability of the Diesel engine.

(1057) TURBINE WELL PUMPS. Bulletin H-450-B27A, by Worthington Pump and Machinery Corporation, Harrison, New Jersey, shows pictures of several turbine pump installations and gives a vertical section through one of their motor driven direct connected pumps with side notes giving a brief description of each part of the pump.

(1058) AUTOMOBILE FACTS. June issue of the Automobile Manufacturers Association, Detroit, Michigan, bulletin "Automobile Facts" stresses that the high capacity of motor plants is due to intense specialization of machines, versatility of management and men. Articles on how motorists help design highways and the highest automobile taxes in history are included.

(1059) RUBBER COVERED CABLE. Publication No. C-45 by Anaconda Wire & Cable Company, 25 Broadway, New York, N. Y., gives uses and specifications on "Sunex Securityflex" their all-rubber cable for heavy duty use. 52 pages of tables and specifications for various capacity cables designed to meet any requirement. Distributed by The Mine & Smelter Supply Co., Denver, Colorado.

(1060) ELECTRIC DROP PIT TABLES. Catalog No. 210-A by Shaw-Box Crane & Hoist Co., Muskegon, Michigan, contains photographs, descriptive material and blue prints of their railroad shop equipment for lifting and moving loads ranging in sizes from small parts to the largest locomotives.

(1061) HARDINGE PRODUCTS. Bulletin No. 100, by the Hardinge Company, York, Pennsylvania, contains short descriptions of each one of their products so the reader can obtain at a glance whatever is of interest to him. Where possible reference is made to complete bulletins on each separate piece of equipment.

(1062) COMPRESSORS. Bulletin WB-10, by Gardner-Denver Company, Quincy, Illinois, describes their class "WB" vertical two-stage water cooled compressors. Cross sectional cuts show mechanical details and pictures of actual installations are shown. Compressor specifications and a table showing ratings and dimensions at sea level, 5,000 feet altitude and 10,000 feet altitude are given.

(1063) MINING EQUIPMENT CATALOG. No. G-4000 published by the Hassell Engineering Company, Colorado Springs, Colorado, alphabetically lists their complete stock of new and used mine and mill equipment. Both f.o.b. and f.o.r. prices are quoted for each piece of machinery and terms of sale are stated in the catalog.

(1064) OIL WELL EQUIPMENT. National Supply Company, Toledo, Ohio. Bulletin No. 278, on type DR and type DRC rotary drive transmissions. These chain type rotary drive transmissions are offered to provide a means for obtaining a greater range of speeds to the conventional rotary machine on an Internal Combustion Engine Rotary Rig. Bulletin No. 279 on their "Ideal" machine cut sprockets. The distinguishing feature is their very accurate tooth form which assures proper and uniform loading and release of the chain rollers and sprocket teeth. Bulletin No. 277, describes types TE-30 and XE-30, 300-ton capacity hydraulic weight indicator. Bulletin No. 174-B gives specifications, horsepower curves and descriptive information on the Superior vertical two cycle type FB gas engine.

(1065) MATERIALS HANDLING. Form No. G-1031, by R. G. Le Tourneau Inc., Peoria, Illinois, presents a study of modern handling methods for controlled low-cost production. Clearing, stripping, ore handling, road building and odd job methods of handling are discussed. Pictures showing the use of Le Tourneau equipment accompany these discussions.

(1066) POWER PUMPS. Bulletin FX-10, Gardner-Denver Company, Quincy, Illinois, explains the advantages of their type "FX" duplex power pumps for slush and cement service. Cross sectional cuts showing the working parts of the pump are supplemented with specifications and pictures of the pump completely assembled.

(1067) H & B BULLETIN for July-August contains detailed information on the largest deaerating type feed water heater in this section of the country. This unit was installed at Lowry Field's new power plant. The rest of the bulletin is devoted to many of the products sold by the Hendrie & Bolthoff Mfg. and Supply Co., 1635 17th St., Denver, Colorado.

(1068) LINK-BELT NEWS for July-August published by the Link-Belt Company, Chicago, Illinois, contains articles on crushing coal with minimum degradation, 21 miles of steel pile driving for N. Y. highway and numerous

(Continued on page 466)

Alumni Business

OFFICERS OF ALUMNI ASSOCIATION

EDWARD J. BROOK, '23
President

FRANK C. BOWMAN, '01
Vice-President

FRANK J. NAGEL, '03
Secretary

GEORGE W. THOMAS, '26
Treasurer

FRED C. CARSTARPHEN, '05
Denver, Colo.

M. EDWARD CHAPMAN, '27
Tulsa, Okla.

CHARLES O. PARKER, '23
Denver, Colo.

✦

COMMITTEE CHAIRMEN

BRUCE B. LaFOLLETTE, '22
Publications

JAMES W. DUDGEON, '13
Athletic

ALLAN E. CRAIG, '14
Capability Exchange

KEPPEL BRIERLY, '34
Instruction

RUSSELL H. VOLK, '26
Membership

T. C. DOOLITTLE, HON. '27
Budget and Finance

C. LORIMER COLBURN, '07
Alumni Foundation

A. GEORGE SETTER, '32
Legislation

DONALD DYRENFORTH, '12
Public Relations

HUGH M. CONNORS, '22
Research and Investigations

KENNETH E. HICKOK, '26
Nomination

W. A. WALDSCHMIDT, Faculty
Junior Membership

✦

PUBLICATION COMMITTEE

BRUCE B. LaFOLLETTE, '22
Chairman

J. HARLAN JOHNSON, '23
Vice-Chairman

CHARLES W. HENDERSON, HON. '30
FRED C. CARSTARPHEN, '05
JOHN H. WINCHELL, '17
CLAUDE, L. BARKER, '31
RUSSELL H. VOLK, '26
ARTHUR W. BUELL, '08
W. A. WALDSCHMIDT, Faculty

MEETINGS

Executive Committee Meetings

3rd Monday of each month, Alumni Office, 7:00 P.M.

Alumni Council Meetings

4th Thursday of each month, Argonaut Hotel, 6:30 P.M.

Publication Committee Meetings

2nd Tuesday of each month, Alumni Office, 7:00 P.M.

Magazine Staff Meetings, Alumni Office on call.

COLORADO SCHOOL OF MINES ALUMNI ASSOCIATION NEW MEMBERS JULY, 1940

Alumni

Kenneth R. Fenwick, '36 - Forest, Miss.
Harold E. Munn, '17
Mount Isa, Queensland, Australia
Thomas E. Northrop, '32 - Denver, Colo.
E. M. Smith, '05 - Seattle, Washington

Associate

Harry R. Gilger, Ex-'26
Long Beach, Calif.
James R. Winnek, Ex-'29
Los Angeles, Calif.

REPORTS

Executive Committee Meeting

A meeting of the Executive Committee of the Colorado School of Mines Alumni Association was held on July 15, 1940.

Members present: Frank C. Bowman, George W. Thomas, Fred C. Carstarphen, Charles O. Parker, Frank J. Nagel. Committee chairmen: James W. Dudgeon, Russell H. Volk, C. Lorimer Colburn. Guests: George H. Roll of New York, Coach John Mason.

Treasurer's Report

Treasurer's report was submitted by Treasurer Thomas. This showed the Alumni Association's finances to be in satisfactory condition with a slight slowing up in the payment of dues. A decline in surplus of $108.50 from previous report was noted.

Athletic Committee

Chairman Dudgeon presented the report of the Athletic Committee.

Alumni Scholarships

The manner of notification of successful applicants for Alumni scholarships was discussed. The names of two applicants who had submitted satisfactory credentials and had been awarded scholarships were announced. Other applicants who had yet to qualify in entrance requirements were discussed and the earnest manner in which some were going after deficiencies assures that all five Alumni scholarships will be filled.

Alumni Loan Fund

Need for funds to help worthy students was noted and Chairman Dudgeon advised that an immediate appeal for funds for this worthy help to students would be made. Various methods for raising money by Local Sections were discussed but it was decided that President Brook should assign a quota to each section and they might use their own methods in raising same.

Repayment of loans by students now out of school was discussed and it was hoped this would help men now in school.

C. O. Parker explained the methods and objections of the Alumni Loan Fund to George H. Roll of the New York Local Section and solicited the aid of that body in putting to work a part of their, at present, inactive fund.

Membership Committee

Chairman Volk presented the report of the Membership Committee which included that four new members and two associate members were received into the Association during the month of June.

Ways and means of getting a 100% membership were discussed and further membership drives will be made.

General

Coach Mason explained the varied work of a modern football coach but expressed the opinion that *Mines* would have a fighting bunch in football suits this year.

Adjournment

Meeting adjourned due to closing of the building.

Local Section Contest

In order to promote interest in Local Sections of the Alumni Association and to furnish incentive for this interest, the Executive Committee are sponsoring and initiating a "Local Section Activity Contest" for 1940. A trophy will be presented to the winning section.

The contest will be based upon the following rating system using 1000 per cent as perfect:

1. Membership (Ratio of Association members to all Miners in locality)	.500
2. Chapter organized on Committee basis, holding regular stated meetings and reporting activities to association secretary	.100
3. Per cent attendance at regular meetings of local section	.100
4. Per capita contribution to Student Loan fund	.100
5. Per capita advertising sales for Mines Magazine	.100
6. Jobs obtained for Mines men (per capita)	.100
	1000

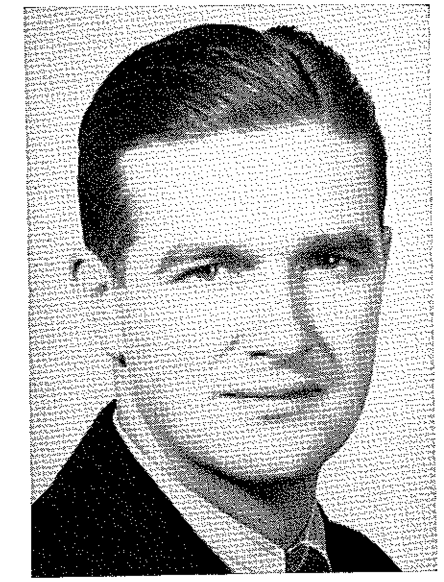
This system is so devised that it can be applied either to a small or large section without penalty. For example: Membership—if from a chapter of 200 residents all were Association members a perfect score of 500 would be awarded. However, if only 75 were members the points would be $\frac{75}{200} \times 500 = .187$. Item two is self-explanatory and should automatically place 100 points to your credit.

(Continued on page 457)

President's Message

Several alumni have recently written to suggest that considerable confusion exists in the minds of our membership as to the purposes of the various funds with which the Alumni Association are concerned. A brief discussion of these funds follows, which may clarify the misunderstandings mentioned in these communications.

There are three funds, existing and proposed, which have been established and sponsored by the Alumni Association. These are (1) The Colorado School of Mines Foundation, (2) Alumni Endowment Fund and (3) Alumni Loan Fund.



E. J. Brook, '23

The Colorado School of Mines Foundation was established by the Colorado School of Mines Alumni Association May 17, 1928 and is the oldest of the three funds. The purpose for which it was formed is given in the introduction.

"The Colorado School of Mines is a state institution. It was established by the Territory of Colorado and is maintained by a state mill levy.

"In recent years this School has come to be more and more of an international institution. The majority of the students come from other states than Colorado and from many foreign countries. The School's popularity is so great that it has difficulty in accommodating the undergraduate and graduate students who make application for admission.

"State support is not adequate to meet the demands of today. Hence, the Foundation whose purposes are to obtain endowments so that the highest type of faculty can be maintained; to receive gifts for more adequate buildings and equipment; to endow scholarships for assisting worthy students, and to establish fellowships whereby competent men may do advance work, in cooperation with the research department of the school, on pertinent problems that are now confronting the mineral industries.

"The proposed articles of incorporation and the by-laws of the Foundation establish a permanent organization so that gifts of any nature may be administered according to the wishes of the donor. The flexibility of these instruments enables the Foundation to meet any contingency that may arise. It is governed by a Board of Directors selected in such a manner that the income from the Foundation will be used for the best interest of the School. The invested capital, nevertheless, will be handled by a trustee (a bank or trust company) thoroughly versed in financial matters and best qualified to conserve the principal and secure the largest earning power with safety on the money or property contributed to the Foundation.

"Through this organization, the Alumni Association extends an invitation to every individual throughout the world, who is anxious to see the engineering profession advance, to join in this endeavor. The needs of the School are many and the donor can provide funds for the purpose which he considers the most urgent."

Alumni and friends of the school have subscribed $7,506.86 to the fund to date, with interest on savings.

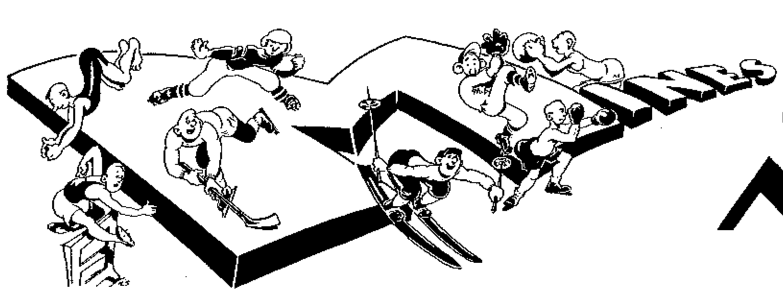
The Alumni Endowment Fund was inaugurated this year as a method of solving the major financial and administrative problem of the Association. Alumni leaders are of the opinion that the volume of work of the Association makes it necessary that a salaried Association Manager be employed. Only thru the employment of such a Manager can the activities of the Association be properly coordinated and directed. The income from membership dues and Mines Magazine just about meet the budget for the "office force" and the publication. Members of your executive committee, after studying the problem believe that the interest earnings of an Alumni Endowment fund of one hundred thousand dollars will provide sufficient revenue to augment the earnings of the Association to an extent which will permit a new administrative set-up under an Association Manager. This fund is still a vision.

Four years ago the Association received the generous cooperation of the Board of Trustees and the Administration of the school in sponsoring five Alumni Scholarships a year at Mines. The general policy in awarding scholarships has been for the Alumni Association to favor applicants who would be financially unable to attend college without such help. In order to provide funds for fees, books and other expenses the "Alumni Loan Fund" was devised. This fund provides help thru loans to students sponsored by the Alumni Association. It will become a revolving fund as the recipients graduate and begin to repay their loans. It is certainly expended upon a worthy cause—that of aiding youngsters to obtain an education.

This fund should receive the generous support of each and every alumnus. Instead, some "piddling" contributions are received which continually force the administrators of the fund to "scrape bottom" to function in a most inadequate manner. A former President of your Association sums the situation up quite appropriately with the words "It seems almost criminal to me that with twenty-five hundred graduates of a school, a simple direct letter of appeal to them does not bring in sufficient funds for the needs of students we have sponsored."

Your Association is asking contributions to the Alumni Loan Fund immediately to meet a critical situation. We have a moral obligation toward Alumni sponsored students. I hope we don't lightly wash our hands of this responsibility. This responsibility rests on each member!

Three funds exist thru which Mines Men can contribute to the financial support of activities on behalf of the school, the Association and students to suit the field of endeavor in which the donors are particularly interested. Mines Men have assumed an indifferent and passive attitude toward any activities involving financial responsibilities and obligations. This attitude should be changed if the Association is to reach the development of which it is capable. This attitude should change if the individual himself is to reach his full development.



Sports March

By HENRIETTA CAMPBELL

Publications Office, Colorado School of Mines

When the general public refers to "dumb athletes" they are certainly not considering athletes from the Colorado School of Mines. Much has been said of the ability of *Mines'* football, basketball, and track stars to maintain high scholastic records so it was really no great surprise to discover that the majority of the outstanding graduates who received awards at the 1940 commencement were also outstanding stars of the athletic department.

Herbert Thornton, Gardner Blythe, and George Yeager were three of the football players honored at their graduation, May 24. Thornton was selected the best center in the Rocky Mountain Conference while Yeager and Blythe played as guards on Mines' undefeated and untied team.

Thornton came to *Mines* from Summitville, Colorado and was quickly recognized as a leader on the campus. A member of the Alpha Tau Omega fraternity, Theta Tau, professional engineering fraternity, Press Club, M Club, Board of Publications, American Society of Mechanical Engineers, "plucky Herb" still found time to maintain an enviable scholastic rating and become a member of the Tau Beta Pi, honorary scholastic engineering fraternity. With this record of scholarship and service for four years at *Mines,* it was natural that Thornton should be awarded the Thomas S. Harrison award for meritorious work in petroleum engineering and have a position awaiting him with one of the major oil companies of Oklahoma.

Gardner Blythe, a Philadelphia man, served with the Merchant Marine before coming to *Mines*. He received all his football training from Coach Mason.

"Gard's" personality and naval training soon brought him into the limelight. He became a member of Sigma Phi Epsilon fraternity, Scabbard and Blade, Theta Tau, Military Ball committee, served as class officer three years, president of the "M" club his junior year, and treasurer his senior year. As the cadet officer displaying the greatest military efficiency, Blythe was presented the James Underhill award.

Upon graduation Blythe found himself reluctant to leave Colorado so he secured metallurgical work in Denver and remained.

COLORADO MINES FOOTBALL

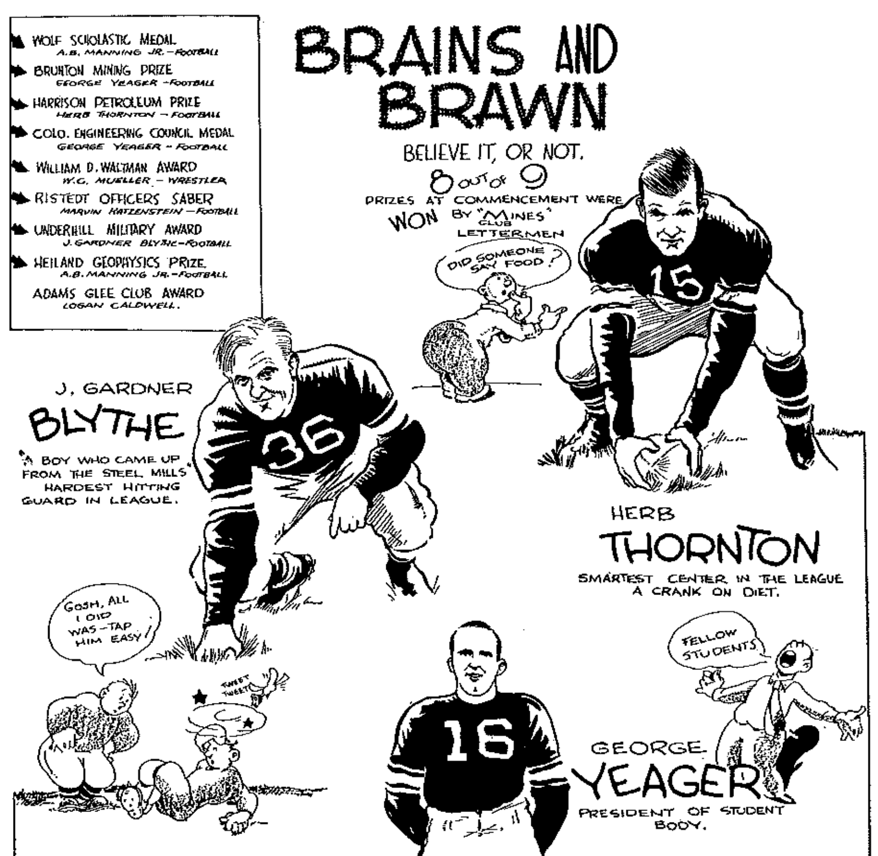
1940

Sept. 28—COLORADO STATE - AT DENVER
Oct. 5—Creighton - - - - at Omaha
Oct. 12—GREELEY STATE - AT GOLDEN
Oct. 19—Colo. College - at Colo. Springs
Nov. 2—MONTANA STATE - AT GOLDEN (Homecoming)
Nov. 9—Western State - - at Gunnison
Nov. 21—Fresno State - at Fresno, Calif.

Two coveted awards were given George Yeager when he received the degree Engineer of Mines. For his meritorious work in mining engineering, he was awarded a Brunton transit, and for his excellence in scholarship, high integrity, and general engineering ability Yeager received the Colorado Engineering Council Medal.

Like Blythe, Yeager was keenly interested in military training and was appointed cadet commander by Colonel Gee at the 1940 military inspection. He also belonged to Scabbard & Blade and Theta Tau. While a senior he published the football program, was captain of Scabbard and Blade, and president of the student body council.

Scholars, athletes, and gentlemen, these men carry the Colorado School of Mines seal of approval and the sincere desire for their continued success.



FROM THE Local Sections

BAGUIO

L. W. Lennox, '05, President; Frank Delahunty, '25, Vice-President; T. J. Lawson, '36, Secretary-Treasurer, Box 252, Baguio, P. I. Monthly dinner meeting third Wednesday each month.

BIRMINGHAM

Tenney C. DeSollar, '04, President; W. C. Chase, Ex-'05, Vice-President; Hubert E. Risser, '37, Secretary, Flat Creek Alabama. Meetings upon call of secretary.

BAY CITIES

Frank Hayward, '32, President; William J. Rupnik, '29, Secretary-Treasurer, 714 Hillgirt Circle, Oakland, Calif. Four meetings per year, 2nd Monday, March, June, September and December.

BUTTE

E. S. McGlone, President; H. M. Strock, '22, Secretary, 1309 Platinum St., Butte, Mont. Meetings upon call of Secretary.

CHICAGO

A. L. Lynne, '06, President; M. E. Frank, '06, Secretary, 4537 Drexel Blvd., Chicago. Meetings upon call of secretary.

CLEVELAND

K. D. True, '35, President; R. J. Maloit, '37, Secretary-Treasurer, 9701 Lamont Ave., Cleveland, Ohio. Four meetings during year, 4th Friday, March, June, September and December.

Dent L. Lay, '35, President; R. J. McGlone, '27, Vice-President; A. L. Mueller, '35, Secretary, 430 E. 11th Ave., Denver, Colo. Four night meetings per year. July, October, January, April.

Colorado Section of the Colorado School of Mines Alumni Association held its first night meeting under the new policy of four night meetings yearly at the Oxford Hotel on July 19th. The meeting was highly successful and seemed to be the tonic that Colorado Section has needed for some time. Although attendance was far better than was usual for noon luncheons it was below the estimate. Meetings in the future should grow to fairly large proportions with prospects as they are now.

President Lay opened the meeting by asking each member to give his name, class and occupation. This was necessary because of the large number of out-of-town Miners that were present. Committee chairmen were called upon to give their reports. Those that reported were Ellsworth Watson, Bruce LaFollette, Earl Durbin, and Merle Rosengren. Each told what their committee was doing and plans for future progress of Colorado Section. A short intermission was called at which time President Lay circulated a petition for the members to sign which was a form of voting for Lloyd Madden as a candidate for the All-Star Team which is to play the professional team in Chicago this fall. After everyone enthusiastically signed the petition the meeting was turned over to Mr. Bruce LaFollette who introduced the main speaker of the evening, a former Mines man, now Major L. H. Dawson, Operations Officer at Denver's new army airfield. Major Dawson delivered one of the finest and most interesting talks that Colorado Section has heard this year. His subject was "Our National Defense," a most vital business at this time. After his talk, Major Dawson answered many questions although beforehand it was made plain that no questions of a divulging nature could be answered.

President Lay closed the meeting by reminding all members of the next meeting date, October 18th, hinting that it would probably be of a football nature.

Members present were:

A. George Setter, '32; P. A. Archibald, '35; Ray McBrian; James Boyd, '32; Neil Bosco, '35; Dart Wantland, '36; Bob Spalding, '33; C. D. Kerr, '30; Neil Johnson, '33; Dean J. R. Morgan; F. J. Laverty, '25; T. Adams, '29; C. S. Knox, Ex-'27; F. H. Stewart; H. M. Connors, '22; C. B. Ellis, '39; A. A. Klamann, '20; J. W. Bucher, '02; A. E. Bellis, Fac.; Geo. Thomas, '26; Wm. C. Aitkenhead, Fac.; C. B. Carpenter, Fac.; F. Bowman, '01; W. H. Paul, '96; E. Durbin, '36; M. S. Rosengren, '35; B. LaFollette, '22; H. W. Kaanta, '15; W. B. Patrick, '09; F. Steinhaur, '99; V. K. Jones, '10; Ross R. May, '12; August Chatin, '16; E. Watson, '30; J. Demmer, '36; H. Lutz, '36; R. McGlone, '27; J. Hutton, '25; C. W. Turnbull, '31; Nick Watts, Ex-'26; C. Albi, '18; F. McClean, '36; W. C. Klein, '31; J. Stubbs, '26; J. Ruth, Ex-'21; D. L. Lay, '35.

Clark W. Moore, '32, President; R. J. Schilthuis, '30, Secretary, 1410 Gustav, Houston, Texas. Dinner meeting, second Friday of month. 6:00 P. M., Lamar Hotel, Houston, Texas.

The Houston Chapter held its regular monthly meeting on Friday, July 12, at 6 P.M. in the cafeteria of the Lamar Hotel. Those present were:

B. B. Boatright, '22; M. E. Danitschek, '40; P. C. Dixon, '31; R. L. Gibson, '30; R. W. Harrison, '33; J. H. Waterhouse, Ex-'41; L. O. Storm, '40; A. G. Wolf, '07.

Messrs. Danitschek and Storm are newcomers, having recently been employed by Sinclair and Shell, respectively.

LOS ANGELES

R. S. Brummett, 26, President; William Dugan, Ex-'12, Secretary, 315 West 9th St., Los Angeles, Calif. Four meetings during the year, 2nd Monday of month, January, April, July and October.

MANILA

A. F. Duggleby, '15, President; Ralph Keeler, '31, Secretary, Box 297, Manila. Dinner meeting, first Friday each month.

NEW YORK CITY

C. L. French, '13, President; Ben W. Geddes, '37, Secretary, 1112 University Terrace, Linden, N. J. Meetings upon call of secretary.

SALT LAKE CITY

Otto Herres, '11, President; Kuno Doerr, Jr., '27, Secretary, 700 McCormick Bldg., Salt Lake City, Utah. Meetings upon call of secretary.

SEATTLE

Axel E. Anderson, '04, Seattle, Wash., President; Louie C. Rhodes, '20, Spokane, Wash., Vice-Pres.; R. Kenneth Burgess, '28, Portland, Ore., Vice-Pres.; Daniel L. Beck, '12, Secretary-Treasurer, 1020-21 Lloyd Bldg., Seattle, Wash. Meetings: 2nd Monday, September, December, March, June. Visiting Mines Men please notify secretary and called meetings will be arranged.

PHOENIX

Two meetings in year, second Saturday in April and October. T. E. Giggey, '34, President; A. F. Hallett, '09; Percy Jones, Jr., '08, Vice-Presidents; E. M. J. Alenius, '23, Secretary-Treasurer, Box 2751, Phoenix, Ariz.

PITTSBURGH

S. L. Goodale, '04, President; A. M. Keenan, '35, Secretary, Box 146, Pittsburgh, Pa. Meetings upon call of secretary.

TULSA

John R. Evans, '23, President; D. H. Peaker, '32, Secy.-Treas., c/o The Carter Oil Co., Tulsa, Okla. Meetings upon call of secretary.

WICHITA

Thomas H. Allan, '18, President; John T. Paddleford, '33, Secretary-Treasurer, 429 First National Bank Building, Wichita, Kansas. Meetings upon call of secretary.

Western Canada—

(Continued from page 392)

ably the same Lower Cretaceous sands that yield oil in wells in the Lloydminster-Vermilion-Wainwright area and show oil saturated sands at many other points, it seems probable to the writer that the area of more or less oil saturated Lower Cretaceous sands may be 50,000 square miles or more, and that over at least a portion of this area oil may be recovered by wells of relatively shallow depth.

The best results will be obtained where optimum combination of depth, reservoir pressure, reservoir water, reservoir sand characteristics, and quality of oil occur.

To the dyed-in-the-wool (not necessarily sheepherder) geologist, the problems of a sedimentary section that extends from Algonkian to Tertiary and an array of geologic structure that runs the gamut, are sufficient to keep him on the trail without other appeal. But other appeal there is in plenty,—mountain, cirque, and glacier above timber line, all in sedimentary rocks; foothill and plain; forest and grassy prairie. Mountain surveys are enlivened by bears, mountain goats, and herds of mountain sheep. Elk, moose, and deer are familiar sights in the forests. On the plains curious antelope thoroughly investigate all technical procedure.

Canadian winters are long but, particularly in Alberta, not so tough but that both exploratory and development work can be, and are carried on. But when occasionally old Boreas does go on a rampage, the inveterate oil hunter will not turn southward, but with true trapper spirit, innate or acquired by association, will burrow through his subsurface data, run his stratigraphic trap lines, and dream through 15 hour nights about the oil hunting he will do next summer throughout 18 hour days.

Research in Petroleum Geology—

(Continued from page 400)

tions. There is no differentiation between structures due primarily to differential compaction and those originally outlined in this manner but which had their dips materially increased by one or more later periods of folding. And in many instances, salt core structures are not distinguished from those produced in other manners. Such deficiencies promise to be corrected as time goes on. Other things being equal, the structures of more complex history are more likely to carry oil and gas.

The time of folding in reference to the time of migration and accumulation of oil and gas will receive more attention in specific areas. The evidence points to the fact that the hydrocarbons may have moved through certain areas before structural traps were formed. In other cases where two or more periods of folding are involved, there is evidence that migration and accumulation are related primarily to only one of these disturbances. More specific data regarding such relations should materially advance the science of petroleum geology.

The puzzling variations in elevation of the oil-water contact around the edges of certain California and other anticlinal pools is deserving of more careful study. Is this the result of renewed movements and lag in adjustment of the oil-water contact, or is it explainable upon the basis of eccentricities in accumulation related to regional structure or possibly to modifications resulting from flushing or comparatively recent migration and accumulation of oil?

Miscellaneous Problems

Other lines of study which suggest themselves are: (1) the import and physical state of the nickel, vanadium, and other comparatively rare elements in some crude oils; (2) the cause and meaning of the relatively high temperatures found in the edge waters of oil pools (3) a comparative petrographic study of the sands in productive and nearby barren structures of similar development; (4) a chemical and petrographic study of the oil sands and associated sediments where the oils vary considerably in character or where oil gives way to gas in the same sand in associated structures of like age and kind; and (5) the significance and effect of bacteria in the edge waters of many oil fields.

Summary and Conclusions

Many of the problems suggested may appear to be of purely academic interest today, but their solution might prove to be of great practical importance sometime in the future. However, if we should concentrate now only on those questions which have an immediate application, our efforts should be well worth while.

Not all of the problems are purely geological in nature and their solution will entail the cooperation of physicists, chemists, bacteriologists, and other scientists.

The ordinary difficulties encountered in experimental work in petroleum geology are multiplied because of the many variable factors involved in the development of even the simplest type of accumulation of oil and gas. We are also handicapped by our inability to reproduce the time element on a satisfactory basis. In nature, tens of thousands of years were undoubtedly involved in the development of certain phenomena, but in the laboratory we are usually limited to days or weeks in our experimental procedures.

Petroleum geology will never be reduced to an exact science, but if we can discover the relative importance of the factors involved in the fundamental processes, we shall have traveled a long way towards the simplification of the principles of this branch of systematized knowledge.

Hugoton Gas Field—

(Continued from page 408)

the appearance of being all one formation it probably spans a long interval of time. Darton gives the age as late Miocene and Pliocene, but mentions some Pleistocene deposits which are difficult to distinguish from the Ogallala. Johnson[7] is responsible for the idea that the mortar beds represent the old stands of the ground water table.

Most of the water wells in this region are drilled to porous phases of the Ogallala or to its base and contact with underlying beds which are less porous.

QUATERNARY SYSTEM

Dune Sand

A strip of sand dunes about six miles wide is found on the south side of the Arkansas River across Hamilton and the west half of Kearney County, Kansas. Beginning just south and west of Lakin this band of dunes widens to about eighteen miles in southern Finney County. Other smaller strips of sand dunes are found along the south bank of the Cimarron River in Morton County, Kansas, in the valley of the North Canadian River in Texas County, Oklahoma, and in isolated patches on the plains in Central Stevens County, Kansas, both north and south of Hugoton.

These dunes form a thickness of sand usually less than seventy-five feet but they completely dominate the landscape in the area in which they occur. They present an effective barrier to transportation on all roads except the macadamized state highways. The sandy soil is worthless for farming, although in wet seasons there is enough vegetation on the dunes to furnish a poor pasturage.

Between 1934 and the present date, with unusually arid seasons, there has been considerable migration of the sand dunes and consequent extension of the untillable territory. When vegetation is absent there is very little difference between the shifting sandy soil of the Ogallala formation and the area of Quaternary dune sand.

[7] W. D. Johnson, "High Plain's and their Utilization," *United States Geological Survey, 21st Annual Report*, (1901) pt. 4.

STRUCTURAL GEOLOGY

As shown by the structural contour map and the east-west cross section, the dominant structural feature in this region is a monoclinal dip toward the east, at the rate of about fifteen feet per mile. Essentially the same structure can be shown on the top of the Herington, the base of the Winfield, or the base of the Florence formations, making it evident that the date of the orogeny is at least post-Herington.

A few reversals of this monoclinal dip are to be found. Along the Stevens-Morton County line there is a small but definite closure, and several broad noses and terraces may be observed. Our map, using the one hundred foot contour interval, tends to emphasize the general monocline rather than the detail possible in a local study.

ECONOMIC GEOLOGY

Three hundred and twenty-two gas wells have been drilled in the area since 1922, two hundred and eighty-eight in Kansas and thirty-four in Oklahoma. The most recent open flow tests show that the total present open flow of the wells in Kansas is approximately two billion six hundred million cubic feet, or an average open flow of about eight million cubic feet per well. The total present open flow of the wells in Oklahoma is approximately four hundred and fifty million cubic feet, or about thirteen million cubic feet per well. The initial rock pressure on these wells varied from four hundred and forty to four hundred and thirty-two pounds per square inch and the present rock pressure average of the Kansas wells is four hundred and thirteen pounds. In the last four years one hundred and sixty wells—some as much as ten years old, others newly drilled—have been acidized, thereby increasing their average open flow from four million seven hundred thousand to thirteen million eight hundred thousand, an average increase of one hundred and ninety-five per cent. Individual wells have increased from twenty-five per cent to over one thousand per cent through acidizing.

The total production up to January 1, 1940, is between one hundred and eighty and one hundred and ninety billion cubic feet of gas. The writers[8] have made an intensive study of the behavior of some of these wells. The conclusions of this study were presented at the April, 1940, meeting of the American Association of Petroleum Geologists and will be published in the *Bulletin* of the Association at an early date.

[8] Glenn G. Bartle and Rufus M. Smith, "The Relative Porosity and Permeability of the Producing Formations of the Hugoton Field as indicated by Gas Withdrawals and Pressure Decline."

Alumni Business—

(Continued from page 452)

Items three, four, five and six will be given a perfect score of 100 points to the chapter leading in that particular activity. All other chapters will be calculated in proportion to this chapter for point award. For example, if the chapter "A" having the best attendance record (irrespective of size) in percentage of total members "Turning out" for meetings is 60 per cent and the lowest is 25 per cent, then chapter "A" will be rated perfect and awarded 100 points. Chapter "B" will be awarded $\frac{25}{60} \times 100 = .042$ points.

The Mines Magazine will publish standings of chapters in the contest. If you have any delinquent reports which can help you score, turn them in to the secretary, Mr. Nagel, at once. Please turn your mailing list in at once to the secretary so a check on membership can be made and item No. 1 correctly computed.

Stemming Shots—

(Continued from page 410)

tain conditions provided some impervious material is placed immediately upon the brick to prevent the passage of the sand or cement through it. Any or all of this material may be in the open hole or in the casing; the surface of either may be oil wet, water wet, dry, rough, smooth, paraffin coated, etc., or an almost infinite combination of conditions. The fluid above the solid material may be oil, water, or rotary mud in any proportion. In short, the possibility of analytically establishing a quantitative value for solid stemming resistance to impact is attended by considerable difficulty.

Because of approximate uniformity in a given field of casing size and setting depth, amount and size of open hole below the shoe, and other conditions, and probability that all wells will be producing from the same formation, it is possible to very quickly determine the solid stemming necessary to hold down a given shot in each individual area in a given formation. To accomplish this several things are necessary; first, the exact amount and position of all stemming material in the hole must be known. It is not sufficient to know merely that five yards of pea gravel were used because occasionally due to previous shooting or caved hole, five yards of gravel will fill vertically no more than half a yard would normally fill. If upon shot detonation the fluid in the casing is kicked over the crown blocks, in the absence of this definite information, it would immediately be assumed that five yards was inadequate to confine a shot in that formation. When the next well is shot, probably with more explosive and because of loss in handling, less pea gravel and the shot is completely confined, the bewilderment of the interested parties becomes profound. Had it been known that the first shot had 50 lineal feet of pea gravel over it and the subsequent shot 500 lineal feet, the variation due entirely to cave holes below the shoe, the results would not be so confusing.

The next important item is the matter of records; each shot should be completely reported so that as experience accumulates, the results may be compared. This record should include, among other things, the total depth of the hole, the kind and amount of plugging back material, if any; the kind and length of anchor, if any; the size and kind of shells used and their position in the hole; the make and time setting of the time bomb and the time it fired, so that over a period of time the accuracy of the settings may be determined; the kind and position of the cave catcher or umbrella bridge, if used; kind and amount and position of all material in the hole; and the kind and amount of fluid above the solid material. All data on casing such as weight and grade, setting depth, and how cemented and hole sizes should be recorded. The name of the formation being shot should also be recorded, the name of the shooting company and the kind and amount of explosive used. Finally, the reaction of the fluid standing level full to the surface in the casing at the moment of detonation should be recorded. This may be relatively simple, such as: was not disturbed, kicked up, flowed, followed by instructions to scratch two of the possible three answers. By varying the lineal feet of pea gravel in increments of 50 feet and by careful study of the results of each shot, the optimum solid stemming should soon be discernible from the accumulated data.

"Man and Minerals"—

(Continued from page 446)

Adams: Well, this geophysical exploration is a profitable as well as an interesting business, isn't it?

Mason: You know, I sometimes wonder which would be more fascinating—hunting for oil or hunting for gold.

Adams: You have something there, John. You know, to us here in the West, the story of gold has certainly been most colorful.

Mason: Well, I've always been quite interested in that. Whom can we get to tell us about that?

Adams: Well, Professor Wichmann of the Metallurgy Department has quite a story to tell on that. We'll ask him over next week.

FADE

Announcer: You have just listened to another program prepared and presented in cooperation with the Rocky Mountain Radio Council by the faculty members and students of the Colorado School of Mines, an institution devoted exclusively to the advancement of the mineral industries. Heard on this program were: Dr. C. A. Heiland, head of the Geophysics Department, Dr. A. S. Adams, Coach John Mason, George Gebhardt, and Lee Gibson, seniors in Geophysical Engineering at the School of Mines. Tune in next week at the same time and listen to a discussion about gold. Address any question you may have about this program to the station to which you are listening.

(Music: "Mining Engineer," fading into:)

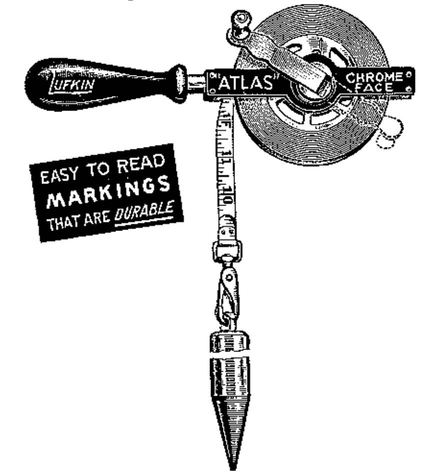
Announcer: The Colorado School of Mines.

(Music swells, then fades)

With the Manufacturers—

(Continued from page 450)

line is easy to locate and the measurement is easy to read, even in poor light. A full line of Chrome Face Gaging Tapes is now offered, including the popular "Atlas," also the others with Plumb Bobs of various patterns.



"Anchor" is the brand of the Chrome Face Tape in genuine leather case. Such Tapes are offered graduated either feet, inches and 8ths or feet, 10ths and 100ths and with lines in both 3/8 and 1/2 inch width. The 1/2 inch is especially suitable for general measuring in the oil industry because its greater width gives it extra durability and it accommodates larger figures.

Chrome Face Tapes are the result of long and careful study and experimentation on the part of The Lufkin Rule Company. While new on the market, their durability as well as readability and other essential qualities have been thoroughly proven through many months of tests under actual, severe conditions of use.

W. H. Kistler Stationery Co., Denver, Colo., is sales representative.

New Valve Development for Temperatures to 1000° F.

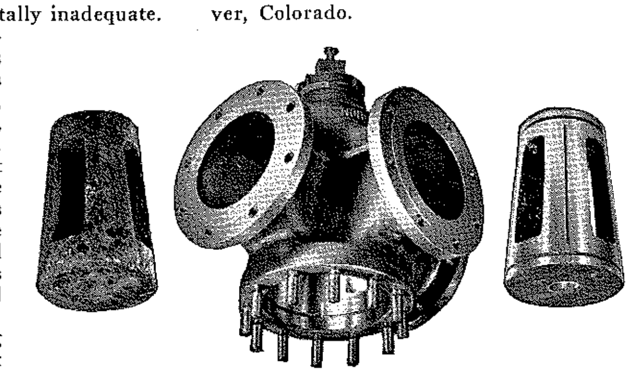
Resistance to Abrasion Increased by Merchrome Coating

After more than two years of factory and field testing, a new valve application is announced. A novel process known as Merchrome coating has been developed by Merco Nordstrom Valve Company. It permits a lubricated plug cock valve to successfully handle services where the temperatures run as high as 1000° F. and where, according to Nordstrom engineers, the operating conditions make the ordinary type of valve totally inadequate.

While the use of Merchrome-coated valves is principally for refineries on hot oil and vapor lines, such as cracking, coking, and topping units, and for mud lines to combat abrasion and erosion, the Merchrome application is expected to gain wide acceptance in chemical plants and in industries where stainless steel valves have limitations.

The Merchrome coating process is a development in which a welded coating is applied to the rotating surfaces of the plugs and bodies and in some cases other parts of the valves. This coating is a complex metal alloy of extreme hardness and corrosion-resistant. Another invaluable characteristic of this coating is said to be its extremely low coefficient of friction. The hardness of Merchromed surfaces is approximately 54 on the Rockwell C Scale and this alloy has the property of maintaining this hardness practically unimpaired at temperatures of 1000° F. The valves are tested before shipment with hot oil at temperatures up to 600° F., and under a pressure equivalent to the intended operation pressure.

A new Bulletin describing Merchromed Valves may be obtained by writing to Merco Nordstrom Valve Company, 400 Lexington Ave., Pittsburgh, Penna.



▼View at Left Shows Merchromed Plug Before Machining; Center View, Body; at Right, Plug After Machining.

New Double-Button Gallet "Multichron"

With the latest TACHOMETER and TELEMETER DIALS. This new time piece has 45-minute register—12 ligne, 17-jeweled, high quality movement. Added time-out feature for sports and industrial use. Its non-magnetic feature is protection for the engineer who comes in contact with electrical equipment. This modern time-piece should form an essential part of every engineer's equipment. William Crow will furnish particulars on request or show you various models at his store, 320 University Building, Denver, Colorado.

Colmonoy Hard-Facing Keeps Equipment on the Job

Service records show remarkable savings being made by COLMONOY, the patented Chromium Boride crystal hard facing material that greatly reduces the ill effects of corrosion and abrasion.

Excessive corrosion by refinery acids, abrasion by sand and solids held in suspension by the crude, galling by packing—all are reduced to the minimum by COLMONOY.

Acid pump plungers, pump sleeves, wash pipes and other wearing parts are particularly susceptible to the difficult abrasion problems of the petroleum industry.

Alloys of COLMONOY crystals and pure nickel have met with remarkable success. Not only is COLMONOY made with varying degrees of hardness, to meet specific requirements, but it is the easiest of all hard metals to apply on steel, cast iron, stainless steel, monel metal, some bronzes and copper.

COLMONOY may be applied as an overlay, by either arc or acetylene gas welding. In addition, it may be cast. In spite of its abrasion resisting qualities it may be machined.

Secure complete information by addressing Wall-Colmonoy Corporation, Department B, Sixth Floor, Buhl Building, Detroit, Mich.

Plant News

Western Knapp Engineering Company reports the recent completion of several modernization jobs in two of California's well known mills.

One was a "change over" for the Carson Hill Gold Mining Co. at Moloneyes.

Flotation cells were installed to replace table concentration . . . jigs were put in for the recovery of free gold . . . and a concentrate regrind mill was included.

Extra pipe lines for a distance of 1600 feet from the concentrator to the cyanide plant, together with the necessary additional pumping equipment were also installed.

The Carson Hill Gold Mining Company is under the general management of J. A. Burgess.

At the Roseklip Mines, Bodie, California, a 500-ton precipitation plant was recently completely installed. This installation was made to treat reclaimed solution from a tailings pond. Additional transformers, power lines and pumping plant were also included to complete this job.

H. N. Sweet is superintendent of the Roseklip Mines Co., and Henry W. Klipstein, vice-president and general manager.

Link-Belt Exhibit Metal Mining Convention Colorado Springs, Sept. 16th to 19th

The Link-Belt exhibit at this convention, Space No. 211, will include—

An operating exhibit of Link-Belt herringbone gear reducer in a transparent case to show the internal mechanism.

A comprehensive display of the latest design of Link-Belt belt conveyor idlers for every type of service.

An attractive back wall panel of photographic enlargements of typical Link-Belt materials handling and power transmission installations in the metal mining industry.

Samples of various types of Link-Belt Shafer anti-friction roller bearings, both mounted and unmounted units; babbitted

(Continued on page 466)

Alcoholic Solutions—

(Continued from page 420)

use of a dilute alcoholic solution presents itself. It is thought that the injection of alcohol into producing wells between periods of production will materially decrease the amount of emulsion formed in producing the oil. It is suggested that further research should be carried on along this line of thought.

The use of a dilute alcoholic aqueous solution will almost double the amount of oil produced by flooding and a suggested method of reducing emulsion has been presented for consideration.

Bibliography

1. Notes on Valuation of Oil and Gas Properties By The Corpus Christi Geologists' Study Group, Page 7.
2. The Effect of Flooding Oil Sands With Alkaline Solutions. Bull. American Association of Petroleum Geologists—Vol. II, No. 3—R. C. Beckstrom and F. M. Van Tuyl.

NOTE:

The author wishes to take this opportunity to thank Mr. Clark F. Barb, Professor of Petroleum Engineering at The Colorado School of Mines, for his cooperation and helpful suggestions in performing these experiments.

Contributions to Petroleum Geology—

(Continued from page 427)

to local civilization as the soldiers. The history of southwestern Matto Grosso is known only on general lines. The most curious fact in the discovery of the Paraguay river is that it was discovered in its central part, from land, and not by ascending it. Alejo Garcia crossed the river after making a land trip from the coast at Santa Catharina in 1525, and established the city of Miranda. Not satisfied with this he crossed the Chaco and established "Ciudad de Charcas" (Sucre) in Alto Peru (Bolivia). At the same time, Caboto ascended the river to Angostura and traded goods with the Guaranís, receiving pieces of silver, among other things, hence the name, Rio de la Plata, or "Rio da Prata" (Portuguese). In 1540 Nunes Cabeza de Vaca went up the river to the country of the Xarayes (sha-ha-ee-ays) Indians, north of Corumbá. In 1546 Domingos M. Irala reconnoitered to the Chiquitano mountains, and borrowed the expedition of Nuflo de Chaney to colonize the region (Brazilian-Paraguayan plateau). Instead they disobeyed orders and founded Santa Cruz to the west in Bolivia, which was the principal reason for this other easterly region being Portuguese territory. In 1648 the Paulista (a resident of Sao Paulo) Antonio Raposo Taveres, a specialist in this type of "razzias" (argument) proceeded to drive out the Spanish, destroying Xerez and traveling clear to the Andes. From here on the history is confused.

In conclusion one of the writers examined the southwest from an economic point of view. He points out the natural economic competition due to the existence of the great market of Buenos Aires, situated at the mouth of the River Plate, into which the Paraguay River flows, and the attraction of the Capital of Sao Paulo, although the transport conditions to the latter are less favorable. Sao Paulo as a market has the advantage of being Brazilian territory. The author concludes that the transport by the River Paraguay should win and it is therefore practical to help this natural tendency, while continuing to uphold the political dominion, which action is taken for granted. Matto Grosso exports chiefly cattle and cattle products. There are about four million head of cattle in this State. With reliable ship service between Matto Grosso and Buenos Aires it is possible that minerals such as iron, manganese, etc., ornamental stones such as phonolites and marbles, could be exported.

Somastic Pipe Coating—

(Continued from page 428)

out of service. This equipment is unique in design and represents the latest development in the application of asphaltic-mastic pipe coating.

Field Joints

It is conceded that several mill wrap coatings are capable of providing satisfactory protection to individual joints of pipe, but in practice the method of applying field joints frequently fails to afford adequate protection at these points. In view of this, it is believed that particular attention should be given to the proper application of a coating to welded field joints.

Somastic field joints are applied under pressure by means of a steel form which casts an extra thick mastic coating which overlaps the existing coating, thus giving absolute protection over the field weld.

Testing

To insure that asphalt-mastic coating is being properly applied, coated pipe is tested for Holidays by means of a Holiday Detector utilizing a high potential. These detectors are maintained as standard equipment available for use on all plant and field jobs.

Laying Coated Pipe

Asphalt-mastic coated pipe can be hauled and strung, roll welded, bent cold in the field, and lowered into the trench and backfilled without damage to the coating. Handling by use of belt slings instead of cable slings, padding of truck bolsters, and padding of bending blocks is recommended. In observing several laying jobs, it has been noticed that the mastic coated pipe can be cold bent in the field on lines up to 10 inches in diameter without damage to the coating. With proper care, lines of larger diameter can be laid by making bends of normal degree of curvature.

Physical Properties of Coating

By reason of its inherent physical properties, a proper asphalt mastic coating will demonstrate its ability to prevent water, carrying soil salts in solution, from making contact with the pipe, and to prevent electrolytic activity from taking place. It has ample tensile strength to resist soil stresses, and sufficient ductility to allow for field bends, and is resistant to impact and strong depression forces.

Thus, we find that the process of Somastic Coating consists of permanently protecting the outer surface of steel pipe lines with a continuous seamless jacket of thick dense asphalt mastic, thoroughly bonded to the pipe, free from Holidays, and with field joints protected by an extra thick overlapping coating.

As of August 1, 1940, Somastic Plants are in operation at Houston, Texas; Philadelphia, Pennsylvania; and Los Angeles, California.

Water Flooding—

(Continued from page 419)

discovery of new fields, taxation, etc., are factors which influence the price of oil. These economic factors make the future of water flooding very uncertain. Although the immediate future may see little advancement, there is no doubt that water flooding will attain a more prominent position in the oil industry.

AMERICAN MINING CONGRESS

Seventh Annual

Metal Mining Convention and Exposition

Colorado Springs, Colorado—
Sept. 16-19, 1940

Everything indicates that the Western Division of the American Mining Congress will stage the greatest of their Annual Metal Mining Conventions in Colorado Springs the week of September 16th. Prominent Mining Men from all over the West will be present. Convention headquarters will be at the Broadmoor Hotel.

The morning session of September 16th will be devoted to Health and Safety. Andrew Fletcher, Vice-President and Treasurer, St. Joseph Lead Company, will discuss Sick Absenteeism. Stanley A. Easton, President, Bunker Hill & Sullivan Mining and Concentrating Company, will tell of the Ultra-Violet Ray Solarium. G. J. Barrett & D. F. Donovan of the Oliver Iron Mining Co. will present a paper on the progress of mine safety. Evan Just, Secretary-Treasurer, Tri-State Zinc and Lead Ore Producers Association, will discuss Propaganda and Practical Experience in Dust Control.

A Welcome Luncheon will be held at the Broadmoor Hotel from 12:15 to 2:15 P. M. Governor Ralph L. Carr, Hon. Edwin C. Johnson, U. S. Senator from Colorado and Geo. D. Birdsall, Mayor of Colorado Springs, will be the speakers. Merrill E. Shoup, Chairman of the Western Division American Mining Congress, will preside.

During the afternoon the visiting ladies will be taken on a sight seeing trip by the Women's Automobile Corps.

At the afternoon session C. K. Leith, Mineral Advisor, National Defense Advisory Commission, will discuss Role of Minerals in the Present War. Elmer W. Pehrson, Mining Engineer, U. S. Bureau of Mines, will discuss Strategic Mineral Procurement, and J. R. Van Fleet, Vice President, U. S. Vanadium Corporation, will discuss Stimulation of Domestic Production of War Minerals.

At 7:00 P. M. in the Little Theater at the Broadmoor Hotel a film will be shown entitled "Arizona—Its Mineral Resources and Scenic Wonders."

At 9:00 P. M. an informal dance, including a gorgeous floor show, will be held at the Hawaiian Village—Broadmoor Golf Club adjoining the Broadmoor Hotel.

At the morning session Tuesday, September 17th, Alexander Goetz of the California Institute of Technology will present a paper on the Industrial Uses of Silver. Richard L. Neuberger of Portland, Oregon will discuss Public Mineral Land Withdrawals. A motion picture film showing the importance of mining in one of the agricultural states will be shown.

A luncheon will be held at the Myron Stratton Home (12:15 to 2:15 P. M.) through the courtesy of the trustees. Dr. R. R. Sayers, Director, U. S. Bureau of Mines, will be the speaker. David P. Strickler, President, Stratton Cripple Creek Mining & Development Company, will preside.

The afternoon meeting will take up new developments metal mine operations and will be divided into two separate sessions. Ira B. Joraleman, President, Desert Silver, Inc., will discuss Mining Geology Today and Robert S. Lewis, Professor of Mining, University of Utah, will tell of New Developments and Equipment in Metal Mines, at one session. Bancroft Gore, Professor of Metallurgy, South Dakota School of Mines, will discuss Progress in Milling Practice, and Charles M. Romanowitz and Herbert A. Sawin, of the Yuba Consolidated Gold Fields, will discuss New Developments in Placer Mining at the other session.

During the day the ladies will be taken on sightseeing trips by the Women's Automobile Corps. At 6:00 P. M. in Fisher Canon at the foot of Cheyenne Mountain there will be the Indian Harvest Festival and Barbecue DeLuxe at which there will be Indian Dancing and songs of the best. At 10:30 P. M. there will be dancing in the Broadmoor Hotel Ballroom.

Under the able direction of Mrs. A. E. Carlton a variety of entertainment has been arranged for the ladies. On Wednesday the ladies are scheduled to have breakfast at the Lodge on top of Cheyenne Mountain and in the afternoon to have tea at Colorado Springs Fine Art Center. The New Mural by Boardman Robinson and exhibits of Chinese art are new on display at the Fine Art Center.

On Wednesday morning, September 18th, Taxation will be the subject to be considered. Ellsworth C. Alvord, Counsel for the Anaconda Mining Company, will discuss National Defense and National Finance. Arthur L. Baldwin of Denver, Colorado, Donald A. Callahan of Wallace, Idaho, and Robert M. Searles of San Francisco will discuss Special Tax Problems of Metal Mining.

At noon the Executive Tax Committee will have luncheon together at the Broadmoor Hotel.

The afternoon session will be devoted to a discussion of the Wage-Hour Act and Mining Loans. Philip B. Fleming, Administrator, Wage and Hour Division, U. S. Department of Labor, will discuss Administering the Wage-Hour Act. Hon. James Murray, U. S. Senator from Montana, will address the convention on Expansion of R. F. C. Loans for Mining.

At 7:30 P. M. an Ice Carnival will be staged at the Broadmoor Ice Palace. Famous Ice Stars will put on a brilliant show.

On Thursday, September 19th, the ladies will be entertained at Breakfast Bridge, (11:00 A. M.) Cheyenne Mountain Country Club.

The morning session of the Convention will be devoted to Labor Problems. Edmund M. Toland, General Counsel, Special Committee to Investigate the N. L. R. B., will tell about the National Labor Relations Board—An Example of Administrative Agencies. C. S. Ching, Director of Industrial and Public Relations, U. S. Rubber Company, will present a paper on Present-Day Industrial Relations. Discussion will then follow by D. D. Moffat, Vice President, Utah Copper Company, and H. M. Lavender, General Manager, Phelps Dodge Corporation.

At noon (12:15 to 2:15 P. M.) there will be a Joint Luncheon at the Broadmoor Hotel for the Board of Governors Western Division and the Board of Directors, American Mining Congress.

At the afternoon session the War's Effect on Metal Mining will be thoroughly reviewed, taking up the War's Effect on Supplies, International Movements, Domestic Markets, Prices, etc., for Copper, Lead, Zinc, Iron Ore, Gold, Silver, Mercury, Tungsten, etc.

The Annual Banquet will be held at the Broadmoor Hotel at 7:00 P. M. R. M. Hardy, President, Sunshine Mining Company, will be toastmaster and the address will be delivered by Hon. Key Pittman, U. S. Senator from Nevada.

Friday and Saturday, September 20th and 21st, have been set aside for the following inspective trips:

Carlton Tunnel—Cripple Creek
Colorado Fuel & Iron Corp.—Pueblo
Climax Molybdenum—Climax
Golden Cycle Mill—Colorado Springs.

Requirements—

(Continued from page 434)

interpretation of the final data, it seems that a client would receive much more for his fee expenditures if the survey were conducted by a personnel whose rank has been established according to the ability, knowledge, and experience of each technical man under a plan which would allow a positively free intercourse of ideas and information among the personnel. It is the belief of the writer that team work among the workers in geophysical exploration is more valuable than competition for rank in the organization. It is further believed that every reflection seismograph crew should be headed by men who have proved that they are capable of carrying on original and creative research in this type of work.

A difficulty which often arises in the course of routine standardized seismograph operations is that a survey is carried out along methods known to succeed in a particular area. If satisfactory data are not obtained the fact is taken for granted without due proof that the interfaces of the geological formations do not give good reflections or that the uppermost layers of the ground respond in such a manner as to make it impossible to secure reflection data from below. This difficulty is demonstrated by operators making several surveys over the same area. It is assumed that each time the area was covered new or better data were secured. Obviously had the men making the survey understood the problems involved all the data could have been secured during the first survey thus avoiding considerable expense and time required to make the extra surveys.

As a conclusion it can be stated that the weakest link in a seismograph service chain is its personnel. A crew personnel which operates and maintains equipment according to a routine set of directions established by standardization are likely to have a very limited knowledge of the fundamental problems of the research at hand. Such a party may succeed under favorable conditions but new problems and difficulties encountered in securing field data may obviously impair the value of the work of the organization. Usually such organizations have experts available to assist in the event of failures but this help often comes too late after the failure is realized.

Although the total cost is usually somewhat higher in securing the services of a seismograph crew whose personnel consists of scientists who have carried on creative research in the seismograph field, and are well informed in physics, geology, mathematics and electronics, the added cost of such a crew above that of a routine standardized crew is insignificant when the final possibilities are considered. Organizations offering personnel of this type are in general limited in their expansion program to only a few crews because of the difficulty in securing and developing adequate personnel. An advantage sometimes found in limited expansion is that this type of organization can economically keep their equipment up-to-date in the way of improvements. When it becomes necessary to rebuild a large number of sets of equipment in order to incorporate new improvements the expense and loss of crew time may be considered too great.

Where there are large areas to be examined and the conditions are very favorable for the prosecution of seismograph work, this is definitely a place where the effectiveness of the routine standardized crew operations can be best realized.

On the other hand areas which are complicated by geological disturbances, rapid changes in geological column, rapid lateral as well as vertical changes in the velocity of the seismic waves, types of overburden which are not favorable for reflection work, folded basement rocks that appear to give reflections which may be confused with possible oil bearing measures, complicated variation of the surface low velocity layer or layers, igneous flow rocks interbedded with sediments, etc. may even tax the ingenuity of the very best personnel possible for a seismograph crew.

In the final analysis time may prove that we are about to experience a period in geophysical work when operators will not be chiefly occupied with the problems of putting seismograph outfits into the field as rapidly as possible. The future tendency may be toward the reduction of the total number of service crews and thus more time and energy may be made available for research, improvements in design, and personnel development. In concluding it is significant to note that only minor and few if any major new improvements in the reflection technique have been developed since the basis of the method was demonstrated over ten years ago.

Interpretations—

(Continued from page 443)

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PERSONAL NOTES

(Continued from page 387)

L. A. Shaw, '25, Chief Chemist for the Shell Oil Company, has moved from Long Beach to Wilmington, California, where his address is Box 728.

Raymond W. Snyder, '37, has a change of address to 406 So. Banker St., Apt. 8, Effingham, Ill. He is associated with the Kingwood Oil Co.

Tom Trumbull, '38, has been transferred from Denver to Albuquerque, New Mexico, by E. I. duPont de Nemours & Co. for whom he is Sales Engineer, Explosives division. He will travel through southern Colorado, northern New Mexico and northern Arizona. His address in Albuquerque is 544 No. Solano Street.

Ronald O. Walker, '24, District Exploitation Engineer for Shell Oil Company, is being addressed at Box 15, Grand Isle, Louisiana.

Hugh A. Wallis, '28, who has been in Venezuela with the Lago Petroleum Company for some time, has returned to the States and is being addressed at present, 1030 East 8th St., Apt. 8, Ada, Oklahoma.

Edwin F. White, '36, Sales Manager for the Denver Machine Shop, resides at 1227 Cherry Street, Denver.

Visitors at the Alumni office recently included: *Keith Buell*, '39, Junior Chemist, Research department, Phillips Petroleum Company, Phillips, Texas; *H. B. Estabrooks*, '38, enroute to Tennessee to take over his new duties as Junior Mining Engineer for the Tennessee Copper Company; *William J. Gilbert*, '06, Chemist, Nevada Consolidated Copper Co., McGill, Nevada; *P. C. Gribben, Jr.*, '31, Assayer, A. S. & R. Co., Rodeo, Calif.; *Harold E. Harris*, '24, A. S. & R. Co., Durango, Colo.; *Charles H. Jenkins*, '29, Engineer, Myles Salt Company, Weeks, La.; *Albert M. Keenan*, '35, Chemist, Preparation department, Pittsburgh Coal Company, Pittsburgh, Penna.; *William Harriss King*, '27, Chemical Engineer, Socony-Vacuum Oil Co., Woodbury, N. J.; *William Homer King*, '28, Mine Foreman, El Portal Works, National Pigments & Chemical Division of National Lead Company, El Portal, Calif.; *Lester D. Knill*, '33, Engineer, U. P. Coal Company, Rock Springs, Wyo.; *H. F. McFarland*, '32, just returned from Transvaal, So. Africa; now being addressed at Shawnee, Wyoming; *George H. Roll*, '19, President, Blade Master, Inc., Pleasantville, N. Y.; *I. B. Williams*, '11, of Tulsa, Oklahoma, who is being addressed in Golden at present.

Information has not yet been received from all members of the class of 1940 as to where they are now located but those who have advised the Alumni office are employed as follows: *Robert Allen*, U. S. Bureau of Mines Experiment Station, Golden; *Norman Amend*, Development section, Phillips Petroleum Co., Phillips, Texas; *Emmett B. Asmus*, Sinclair Refining Co., 4736 Boring Ave., East Chicago, Ind.; *John A. Bailey*, Shell Petroleum Corporation, Covington, Okla.; *James A. Ballard*, Seismograph Service Corp., Tulsa, Okla.; *L. H. Bell, Jr.*, Phil-

(Continued on page 468)

WEDDINGS

Seeburger-Mileau

Lieutenant Francis F. Seeburger IV of the Air Corps, U. S. Army, and Miss Mary Louise Mileau, daughter of Major and Mrs. Alexander Mileau of San Antonio, Texas, were married at Fort Sam Houston on June 20.

Lieut. Seeburger who graduated in 1935 spent three years in metallurgical work before entering the flying service. He was in training at Randolph and Kelly fields and is now stationed at Langley Field, Virginia, where he and Mrs. Seeburger are now at home.

Estabrooks-Elliott

At an evening ceremony in Golden on June 29 Henry Estabrooks of the class of '38 and Miss Gladys Elliott were united in marriage.

The bride, daughter of Mrs. Elizabeth Elliott, was born and reared in Golden and for the past few years has been employed as secretary of the faculty at the School of Mines and more recently for the U. S. Bureau of Mines Research laboratory.

Since his graduation from *Mines* Mr. Estabrooks has been associated with the Canyon Corporation at Deadwood, South Dakota. He recently accepted position of Junior Mining Engineer for the Tennessee Copper Company at Copperhill, Tennessee, where he and Mrs. Estabrooks will reside.

Wagner-Crawford

Announcement was made recently of the marriage of John Robert Wagner and Miss Ann Crawford of Golden which took place on May 31 at the home of Reverend Snyder of Brighton, Colorado.

Mr. Wagner received his degree, Engineer of Mines, this year and is now employed at Grass Valley, Calif.

Hogg-Steele

F. Edgar Hogg and Miss Margaret Steele of Saskatoon, Canada, were united in marriage on July 11 at the home of the bride.

The couple are now at home at Sault Ste. Marie, Ontario, Canada, where Mr. Hogg of the class of '37 is Junior Engineer for the Chromium Mining and Smelting Corporation, Ltd.

BIRTHS

First Presentation
of the
Sweetest Story Ever Told
"Blessed Event"
Featuring
The New Baby Star
Jon Aldridge
Released Through
Twentieth Century Productions
with
Mr. and Mrs. John R. Zadra ('35)
in the roll of adoring parents
History of the Star
First Appearance on April 25, 1940
Approximate Time—7:02 A. M.
Tipped Scales at 8 lbs. 6 oz.
For reservations to see the star in person communicate with the parents.

Mr. and Mrs. Robert B. Kennedy have announced the arrival of Helen Arlene on July 3, 1940. Her weight, 6 lbs. 12 ounces. Mr. Kennedy of the class of '38 is Process Engineer for the Magnolia Petroleum Company at Beaumont, Texas.

Frank Brady Reed arrived at the home of his parents, Mr. and Mrs. E. F. Reed, in Potrerillos, Chile, on June 15, 1940. His weight was 8 pounds, 5 ounces.

His father, of the class of '22, is Chief Engineer and Geologist for the Andes Copper Mining Company at Potrerillos.

Elimination of Peroxide—

(Continued from page 448)

nitric acid. Further experiments were made on ethyl ether and the lead dioxide also reduced the peroxide content without leaving any lead in the ether after filtering. A small sample of diisoamyl ether was found that contained a large amount of peroxide *(.66N)*. This was treated with lead dioxide by shaking for 5 minutes and filtering. The normality of the diisoamyl ether dropped to *.12N*. The sample was not large enough to continue further experiments and therefore this merely indicates that the lead dioxide also can be used to purify this ether. The lead dioxide was used in preference to the Pb_3O_4 because of its greater activity. Dioxane does not react as readily with PbO_2. A sample of dioxane was shaken with lead dioxide with no appreciable result, but when it was refluxed with the lead dioxide, the peroxide content dropped from *.11N* to *.001N* in about ½ hour. No lead could be detected in the dioxane by extracting the distillation residue with nitric acid and testing with H_2S.

Conclusions

Two methods of reducing the peroxide content of dioxane have been developed. The first is to shake the dioxane with stannous chloride and distill off the dioxane. The other is to reflux the dioxane with PbO_2 and filter through a tight filter paper.

Isopropyl and ethyl ether can be purified with respect to peroxides by shaking with PbO_2 and filtering through fine filter paper. From indications previously discussed, probably diisoamyl ether can also be purified by this method.

No lead is present in any of these ethers after the above procedure.

Lead dioxide may be put in the pure ether to preserve it against peroxide accumulation during storage.

Additional work is being done to improve the technique of the procedure and to determine if other oxidizing agents might be effective.

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Letters

TO VACATION IN THE STATES

From C. E. OSBORN, '33

I am enclosing a P. I. postal money order for $5.00 to pay my 1940 dues. I am sorry that I overlooked this matter for so long. Some how I thought that I had sent the money some months ago. The magazine continued to arrive each month so it was not until I received Frank Nagel's letter of May 7th that I was stirred out of my lethargy.

I enjoy each issue of the "Mines" magazine; the 30th Anniversary edition is by far the best yet. My congratulations to the Editor and his staff. A large measure of the success is also due to the contributors. I thoroughly enjoyed J. Harlan Johnson's article about the Mining Murals which were so generously donated by Mr. and Mrs. Barney Whatley. The Colorado School of Mines and its Alumni Association can be genuinely proud of this outstanding gift. I send my gratitude to the donors.

Claude ("Runt") Fertig is now mine superintendent here. We are increasing the capacity of the all-slime cyanide mill from 100 tons to 200 tons daily. The Southwestern Engineering Company, Philippine branch, are the designing and construction engineers for this company.

Mrs. Osborn and I are planning a home leave this fall. We plan to sail from Manila on Sept. 30th via China, Japan, and the Hawaiian Islands. We should be in Denver early in November and are looking forward to renewing contact with many "Miners" and their "Dames" whom we have not seen for the past seven years.

The radio news is coming in from London so I must close to "listen in."

Best regards to all.

Mine Operations, Inc., Rio Guinobatan, Masbate, P. I.

CONGRATULATIONS FROM SOUTH AFRICA

From JACK COOLBAUGH, '31

Just a note to let you know I have received the Alumni Number, April 1940, of The Mines Magazine.

Receipt of this very excellent number may have reached here two months after printing, but I can assure you it was appreciated just as much regardless.

Please allow me to extend congratulations from South Africa to the Association, Editor and Contributors for a very excellent number and for the remarkable improvement in the Magazine as a whole during the past few years.

South African Cyanimid (Pty.) Ltd., Johannesburg

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COMMENCEMENT NUMBER ENJOYED

From RUSSELL J. PARKER, '19

I have read the June issue of the "Mines Magazine" with a great deal of interest and particularly Banks' commencement address.

I notice that Banks refers to an American engineer, residing in London, who was recently President of the Institution of Mining & Metallurgy. I wonder if he realized that the man to whom he was referring was also a graduate of the Colorado School of Mines. I imagine he was referring to Carl R. Davis, who was recently President of the Institution of Mining & Metallurgy, and who graduated from Mines in 1895.

I cannot begin to tell you how much I look forward to seeing the "Mines Magazine" each month. The Magazine more than anything else keeps me in touch with the activities of mining men, and Mines men.

Selection Trust Building, London.

Plant News—

(Continued from page 459)

type bearings, take-ups and other power transmission products; chains for conveyors and drives; samples of Silverstreak silent chain and Silverlink roller chain, including the "RC" flexible couplings.

Link-Belt representatives expected to be in attendance are: E. J. Burnell, vice president, Chicago; N. L. Davis, sales manager, Chicago; W. E. Philips, sales engineer, Chicago; C. M. Schloss and S. C. Shubart, sales engineers, Denver; Rudolph Orlob, sales engineer, Salt Lake City.

All-Wheel-Drive Trucks Have Tremendous Advantages in Oil Production

Oil is where you find it. Usually the most productive fields are located far from paved roads and city streets—in many instances on the very outposts of civilization. Transportation of men, materials and equipment is a major problem.

To meet this problem, and the unusually difficult transportation needs of many other industries as well, The Marmon-Herrington Company of Indianapolis, Indiana, builds a complete line of large and small All-Wheel-Drive vehicles with amazing tractive power and maneuverability. Heavily loaded with seismographic equipment, oil well machinery, pipe line pipe, etc., these vehicles go places where no other trucks could go, do things no other trucks could do. Neither mud, sand, snow nor incredibly steep hills and grades can stop them.

The Marmon-Herrington line consists of 33 models of mammoth extra heavy duty four-wheel-drive and six-wheel-drive trucks with gross capacities up to 70,000 lbs., and conversions to all-wheel-drive of all standard Ford trucks, passenger cars and commercial cars. These latter constitute the only medium and light-weight All-Wheel-Drive vehicles on the market. They are sold at the lowest prices known to the All-Wheel-Drive industry, and are widely used and exceedingly popular in the oil fields.

Inquiries addressed to The Marmon-Herrington Company at Indianapolis, Indiana will bring complete literature and information.

Catalogs and Trade Publications—

(Continued from page 451)

other articles connected with Link-Belt products.

(1069) HAULAGE PROBLEMS. A unique bulletin by the C. S. Card Iron Works Co., Denver, Colorado, asks the miners to vote for Card and encloses several planks in their platform telling why they are well equipped to give first rate service in solving haulage problems.

(1070) NICKEL AND NICKEL ALLOYS. Summer edition of INCO published by International Nickel Co., Inc., 67 Wall St., New York, N. Y., contains articles about many types of equipment using nickel or nickel alloys in their construction. This magazine contains 36 pages of interesting material on the uses and properties of nickel in industry.

(1071) EARTHMOVING. Bulletin by R. G. Le Tourneau Inc., Peoria, Illinois, explains a new faster way of earthmoving with their "Tournapulls." Built to give one-man earthmoving on long hauls. They haul tractor-size loads at truck speeds and spread their own loads to any required depth up to 18 inches. Specifications on the three available models are given along with pictures of "Tournapulls" on the job.

(1072) AUTOMATIC LOADING MACHINES. Bulletin No. 105, by the Eimco Corporation, Salt Lake City, Utah, contains 34 pages of descriptive material, photographs, specifications, sketches and constructional details on model 12-B and model 21 Eimco-Finlay loaders. Several pages explaining track advance, car servicing systems, and loading in many different systems of mining are included. One page is devoted to other Eimco products for the mining industry.

(1073) DECO TREFOIL. August 1940. Published by the Denver Equipment Company, Denver, Colorado, is devoted almost entirely to Vancouver Island and the Zeballos mining area. Geology, ore deposit, mining, power and milling are discussed. Several fine scenery and equipment installation pictures are part of the bulletin.

(1074) CAPACITOR MOTORS. Bulletin GEA-2915A, by General Electric, Schenectady, N. Y., lists the applications, construction, characteristics, modifications, ratings and advantages of their type KC 1/8 to 3/4 horsepower capacitor motors.

(1075) LIGHTNING ARRESTERS. Bulletin R-925-A, by Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., supplements Catalog Section 38-140 on type "LV" autovalve lightning arresters, 20 KV. to 73 KV. A.-C. circuits. Description and outstanding features are given and charts showing list prices, performance characteristics, and mounting brackets are shown.

(1076) GAS MASKS. Bulletin No. EA-6, by the Mine Safety Appliances Co., Pittsburgh, Pa., gives descriptions, specifications and uses for several of their gas masks. Bulletin No. CF-5 lists M.S.A. safety insoles, miner's protection suit, jacket, overalls, skullguards, traveller coat and several styles of safety shoes.

(1077) FLOW METERS. Data Book No. 701-G, by Republic Flow Meters Co., Chicago, Illinois, contains complete specifications covering the construction, principle of operation and application of Republic gas and air flow meters. Divided into five sections headed applications, theory of operation, differential devices, meter bodies and reading instruments. Distributed by the Mine and Smelter Supply Company, 1422 17th Street, Denver, Colo.

(1078) VALVES. Bulletin V-134, by Merco Nordstrom Valve Co., 400 Lexington Ave., Pittsburgh, Penna., shows the new valve which is coated by a process developed to produce a valve especially adapted to refineries where temperatures run from 500° to 1000° F. Full information regarding the advantages of these valves is given in this bulletin.

(1079) ROCK DRILLS. Form 2647, published by the Ingersoll-Rand Company, 11 Broadway, New York, N. Y., is an 8-page illustrated bulletin showing the new R-58 Stopehamer, automatic rotating drill and its many advantages. Full descriptions of the machine together with illustrations on all parts is given.

(1080) SLUSH PUMPS. Bulletin P-234, by Gardner-Denver Co., Quincy, Ill., illustrates the Gardner-Denver Duplex Steam Slush Pump, a semi-portable skid mounted pump for use in the oil fields. Capacity table together with specifications and sectional drawings are included.

PERSONAL NOTES

(Continued from page 463)

lips Petroleum Company; *Robert W. Bennett,* Caterpillar Tractor Co., 210 West Armstrong Ave., Peoria, Ill.; *J. G. Blythe,* Alta Mines, Inc., Ophir, Colo.; *Karl Brueggeman,* Heiland Research Corporation, Canada; *Harry W. Butler,* Sinclair Refining Co., 711 Drew Street, Houston, Texas; *Logan Caldwell,* Pittsburgh Coal Co., Box 285, Smithton, Penna.; *J. Russell Chambers,* A. S. & R. Co., Federal Plant, Alton, Ill.; *Wm. L. Chase.* Empire Mines, Chloride, New Mexico; *Wm. A. Clair,* Carter Oil Co., 911 E. 6th St., Tulsa, Okla.; *Kenneth Clark,* General Geophysical Corp., Houston, Texas; *Roderick D. Clark,* Stanolind Oil & Gas Co.; *Robert F. Connor,* Douglas Aircraft Company, 804 Second St., Santa Monica, Calif.; *John M. Cook,* Arrow Mine, Charleston Mining Co., Mt. Pleasant, Tenn.; *Lawrence P. Corbin, Jr.,* Vanadium Corporation of America, Uravan, Colo.; *Lawrence Corn,* M. W. Kellogg Co., 654 Bergen Ave., Jersey City, New Jersey; *John G. Craig,* Leasing for self, Jamestown, Colo.; *Clarence Crawford,* U. S. Army; *J. P. Crompton,* International Smelting & Refining Co., Tooele, Utah; *George Crosby,* Stanolind Oil & Gas Co., Box 461, Iraan, Texas; *Eugene L. Current,* Seismograph Corporation, Tulsa, Okla.; *Milton E. Danitschek,* Sinclair Refining Co., 711 Drew St., Houston, Texas; *William L. Dennison,* Colorado Fuel & Iron Corp., Pueblo, Colo.; *Gerrit DeVries,* Republic Steel Co., So. Chicago Y. M. C. A., 3039 E. 91st St., Chicago; *E. W. Dissler,* Indian Territory Illuminating Oil Co.; *Donald H. Dowlin,* Pittsburgh Coal Co., c/o E. E. Bowen, R. D. #3, Elizabeth, Pa.; *Reeve M. Duhme,* Mining, Grass Valley, Calif.; *C. Mac Dye,* Tendoy Copper Queen Syndicate, Tendoy, Idaho; *John B. English,* U. S. Steel Co., Cleveland; *L. D. Ervin,* Stanolind Oil & Gas Co., Box 3092, Houston, Texas; *Paul Fillo,* Silver King Coalition Mines Co., Park City, Utah; *Frank Fisher,* Sinclair Development Co., 4736 Baring Ave., East Chicago, Ind.; *Marvin Gantz,* Aluminum Company of America, 3105 Louisiana Ave., Cleveland; *George Gebhardt,* Stanolind Oil & Gas Co., Seismograph Party #23, Morgan City, La.; *Frank Geib,* Ingersoll-Rand Company; *Lee W. Gibson,* General Geophysical Corp., Houston, Texas; *Charles Grimes,* Creede Mills, Inc., Creede, Colo.; *W. E. Heinrichs, Jr.,* Petty Geophysical Company; *Fred Hoel,* Climax Molybdenum Co., Climax, Colo.; *Malcolm Hunt,* International Nickel Corp., Sudbury, Ont., Canada; *S. J. Hussey,* Mahoning Mining Co., Rosiclair, Ill.; *George Jameson,* Minnesota Mines, Wright Hotel, Idaho Springs, Colo.; *George E. Jaynes, Jr.,* Douglas Aircraft Co., Los Angeles, Calif.; *R. K. Johnston,* Esse Laboratories; *Jack Jones,* General Iron Works Co., Denver; *Carl B. Kasch,* Aluminum Company of America; *Marvin Katzenstein,* Alta Mines, Inc., Ophir, Colo.; *John J. Kelley,* Gates Rubber Company, Denver, Colo.; *Arthur Kesling,* Tendoy Copper Queen Syndicate, Tendoy, Idaho; *Robert Knapp,* Aluminum Co. of America, 17 Laurel Ave., Massena, N. Y.; *Forrest F. Lambrecht,* The Texas Company, Box 2332, Houston, Texas; *William R. Lewis,* Ingersoll-Rand Co.; *Maurice Lindsay,* International Nickel Corp., Ontario, Canada; *Addison B. Manning,* Magnolia Petroleum Company; *A. N. McDowell,* Standard Oil Co. of Venezuela, Caracas, Venezuela;

William K. McGlothlin, Climax Molybdenum Co., Climax, Colo.; *I. A. McNab,* Gulf Oil Company; *John D. Moody,* Gulf Oil Company; W. M. Mueller, Aluminum Company of America; *Harold L. Muench,* American Smelting & Refining Co., Leadville, Colo.; *John K. Muller,* Ingersoll-Rand Company; *Fred A. Nagel,* U. S. Gypsum Company, Heath, Montana; *M. E. Natividad,* University of Santo Tomas, Manila, P. I.; *Nicolas Neff,* Gates Rubber Company, Denver; *Robert J. Nekervis,* U. S. Bureau of Mines Experiment Station, Golden; *Carl Nelson,* Standard Oil Co. of Venezuela; *Henry S. Newhall,* Pittsburgh Electro-Melt, Pittsburgh, Pa.; *Joseph L. Oberle,* Caterpillar Tractor Co., 210 W. Armstrong Ave., Peoria, Ill.; *Carl Olin,* Vanadium Corp. of America, Uravan, Colo.; *Earl Palmer,* Indian Territory Illuminating Oil Co., 3606 So. Walker, Oklahoma City, Okla.; *Everett M. Paris,* Climax Molybdenum Co., Climax, Colo.; *Mark S. Patton, Jr.,* Placer mining, Alma, Colo.; *S. F. Peavey,* Mining, Cripple Creek, Colo.; *Joseph Perlman,* General Seismograph Company, Houston, Texas; *Ed Porter,* Colorado Fuel & Iron Co., Pueblo, Colo.; *V. L. Redding,* Continental Oil Company; *Walter E. Redmond,* Nevada Consolidated Copper Co., Box 423, Hurley, New Mexico; *J. A. Richleski,* Bethlehem International Equipment Co.; *David Roberts,* Colorado Fuel & Iron Corp., Steel Works Y. M. C. A., Pueblo, Colo.; *Ben Rummerfield,* Seismograph Service Corp., 709 Kennedy Bldg., Tulsa, Okla.; *William J. Ryan,* Eberhard Gear Works, Denver; *Edward Sawitzke,* Portland Cement Company, 407 So. 5th St., Laramie, Wyo.; *Richard Schaffer,* Gardner-Denver Company, 1843 Humboldt St., Denver; *Howard Schmuck,* Aluminum Company of America; *Henry Schoellhorn,* U. S. Bureau of Reclamation, Denver; *L. A. Shannon,* Veta Mines, Inc., Telluride, Colo.; Nick Shiftar, Stanolind Oil & Gas Co., Owles Hotel, Jennings, La.; *Willard Slater,* Edison Electric Light Co., 1540 West 12th St., Los Angeles; *I. C. Sleight,* Wright Aeronautical Corporation, 16-B No. Maple Ave., Ridgewood, N. J.; *F. E. Smiley,* The Texas Company; *J. C. Stipe,* Fansteel Corporation, Chicago; *Louis O. Storm,* Shell Petroleum Company, 711 Drew St., Houston, Texas; *R. J. Sullivan,* Carnegie-Illinois Steel Co., Gary, Ind.; *Harry Tanaka,* Mitsubshia Company; *James V. Thompson,* Baguio Gold Mining Co., Baguio, P. I.; *Herbert L. Thornton,* Phillips Petroleum Company, 142 So. Pine St., Nowata, Okla.; *Herbert Treichler,* The Texas Company; *E. M. Villareal,* Mining, Old Mexico; *Charles J. Vincent,* U. S. Steel Company, Chicago, Ill.; *A. W. Warren,* U. S. Army; *John R. Wagner,* Mining, Grass Valley, Calif.; *Douglas V. Watrous,* Mining, Idaho Springs, Colo.; *Eugene B. Williams,* Sinclair Oil Co.; *Julian B. Willis,* Sinclair Refining Company, 4736 Baring Avenue, East Chicago, Ind.; *Arthur N. Winsor,* Colorado Fuel & Iron Corp., Pueblo, Colo.; *Gordon R. Wynne,* Ingersoll-Rand Co., Salt Lake City, Utah; *George G. Yeager,* Aluminum Corporation of America, Bauxite, Ark.

The following men will take graduate work this year: *Henry Bowles, A. H. Dramali, Pow Kham-ourai, Charles S. Lindberg, Oliver G. Hesselgren, Jr., Ralph B. Innis.*

The following have accepted positions with mining companies in the Philippines: *A. T. Crisistomo, Rolando Gamboa, Stephen S. Hui, J. L. Jalandoni, M. C. Javellana.*

Patent Service

Recent Patents Relating to the Mineral Industries, edited by James Atkins, registered patent attorney, Munsey Building, Washington, D. C. Inquiries with reference to this subject or to any patents appearing in this department should be addressed to Mr. Atkins.

SEISMIC SURVEYING. Patent No. 2,207,398, issued July 9, 1940, to Francis M. Floyd, Houston, Tex., assignor to F. M. Kannestine, Houston, Texas.

BOTTOM DUMPING CEMENT BAILER. Patent No. 2,207,418, issued July 9, 1940, to Aden F. Sorben, Long Beach, Calif.

BOTTOM HOLE WELL PLUG. Patent No. 2,207,448, issued July 9, 1940, to Elmer J. Ashbrook, Mankins, Tex.

CASING HANGER. Patent No. 2,207,469, issued July 9, 1940, to Richard T. Roye, Houston, Tex., assignor to Gray Tool Co., Houston, Tex., a corporation of Texas.

CASING HEAD. Patent No. 2,207,471, issued July 9, 1940, to John R. Yancey, Houston, Tex., assignor to Gray Tool Co., Houston, Tex., a corporation of Texas.

DEEP WELL PUMP. Patent No. 2,206,461, issued July 2, 1940, to Daniel W. Hoferer, Long Beach, Calif.

DUPLEX PUMP. Patent No. 2,206,466, issued July 2, 1940, to Karl P. Neilsen, Long Beach, Calif.

CONCENTRATION OF ORES AND OTHER MINERALS BY THE SINK AND FLOAT PROCESS. Patent No. 2,206,574, issued July 2, 1940, to Andrew Pearson, Sevenoaks, England.

METHOD AND MEANS FOR PREPARING WELLS FOR CEMENTING. Patent No. 2,206,677, issued July 2, 1940, to Jeff H. Shepler, Houston, Tex.

WELL CONTROL EQUIPMENT. Patent No. 2,206,835, issued July 2, 1940, to Chester A. Combs, Conroe, Tex., assignor of fifty-one and two-thirds per cent to Julius C. Foretich, Conroe, Tex., and forty-eight and one-third per cent to Mrs. J. C. Shelton.

ELECTRICAL LOGGING OR EARTH FORMATIONS. Patent No. 2,206,864, issued July 9, 1940, to Raymond T. Cloud, Tulsa, Okla., assignor to Stanolind Oil and Gas Co., Tulsa, Okla., a corporation of Delaware.

ELECTRICAL LOGGING OR EARTH FORMATIONS. Patent No. 2,206,891, issued July 9, 1940, to Paul F. Hawley, Tulsa, Okla., assignor to Stanolind Oil and Gas Co., Tulsa, Okla., a corporation of Delaware.

LEAKLESS RIGHT AND LEFT TOOL JOINT. Patent No. 2,206,873, issued July 9, 1940, to Alexander Boynton, San Antonio, Tex.

ELECTRICAL LOGGING OF WELLS. Patent No. 2,206,890, issued July 9, 1940, to Paul F. Hawley, Tulsa, Okla., assignor to Stanolind Oil and Gas Co., Tulsa, Okla., a corporation of Delaware.

METHOD AND APPARATUS FOR LOGGING WELLS. Patent No. 2,206,893, issued July 9, 1940, to Paul F. Hawley, Tulsa, Okla., assignor to Stanolind Oil and Gas Co., Tulsa, Okla., a corporation of Delaware.

METHOD AND APPARATUS FOR ELECTRICAL LOGGING. Patent No. 2,206,894, issued July 9, 1940, to Daniel Silverman, Tulsa, Okla., assignor to Stanolind Oil and Gas Co., Tulsa, Okla., a corporation of Delaware.

MEANS AND METHOD FOR LOCATING OIL BEARING SANDS. Patent No. 2,206,922, issued July 9, 1940, to Alonzo L. Smith, Houston, Tex., assignor of twenty per cent to Starr Thayer, Houston, Tex.

METHOD OF AND APPARATUS FOR REDUCING ENRICHED IRON ORES. Patent No. 2,206,973, issued July 9, 1940, to Clarence Q. Payne, Shippan Point, Stamford, Conn.

GRAVITY SEPARATION OF ORES. Patent No. 2,206,980, issued July 9, 1940, to Henry H. Wade, Hopkins, Minn., assignor, by mesne assignments, to Minerals Beneficiation, Inc., a corporation of Delaware.

WELL EQUIPMENT. Patent No. 2,207,001, issued July 9, 1940, to Stephen V. Dillon, Tulsa, Okla.

COMBINATION PACKER. Patent No. 2,207,019, issued July 9, 1940, to George R. Linville, Los Angeles, Calif., assignor to Halliburton Oil Well Cementing Co., Duncan, Okla.

APPARATUS FOR FLOWING OIL WELLS. Patent No. 2,207,033, issued July 9, 1940, to Homer R. Toney, Vivian, La., assignor of one-half to John R. Beddingfield, Shreveport, La.

METHOD AND APPARATUS FOR ELECTRICAL EXPLORATION OF THE SUBSURFACE. Patent No. 2,207,060, issued July 9, 1940, to John Jay Jakosky, Los Angeles, Calif.

LINER CONSTRUCTION FOR SLUSH PUMPS. Patent No. 2,207,112, issued July 9, 1940, to Leslie W. Stahl, Houston, Tex., and Ralph L. Foster, Los Angeles, Calif., assignors to Emsco Derrick & Equipment Co., Los Angeles, Calif., a corporation of California.

FLOW VALVE. Patent No. 2,207,118, issued July 9, 1940, to Charles S. Crickmer and Roy A. Lamb, Dallas, Tex, assignors to Merla Tool Co., Dallas, Tex., a firm of Texas.

FLOW VALVE. Patent No. 2,207,129, issued July 9, 1940, to Word Ray Millican, Dallas, Tex.

METHOD OF CONDITIONING WELLS. Patent No. 2,207,184, issued July 9, 1940, to Harry Calvin White, Los Angeles, Calif.

COMBINED FLUID AND ROTARY DRIVEN DRILLING BIT. Patent No. 2,207,187, issued July 9, 1940, to John S. Zublin, Los Angeles, Calif.

DRILL BIT. Patent No. 2,207,188, issued July 9, 1940, to John A. Zublin, Los Angeles, Calif.

CASING HEAD. Patent No. 2,207,255, issued July 9, 1940, to John A. Jesson, and Samuel Clyde Kyle, San Francisco, Calif., assignors of Seventy-six one-hundredths to said Jesson and twenty-four one-hundredths to R. A. Watson, San Francisco, Calif.

METHOD OF ELECTRICAL LOGGING. Patent No. 2,207,280, issued July 9, 1940, to Lawrence F. Athy and Harold R. Prescott, Ponca City, Okla., assignors to Continental Oil Co., Ponca City, Okla., a corporation of Delaware.

APPARATUS FOR TRANSPORTING MATERIAL IN MINES. Patent No. 2,207,167, issued July 9, 1940, to Charles E. Stoltz, Chicago, Ill., assignor to Goodman Mfg. Co., Chicago, Ill., a corporation of Illinois.

SEISMIC METHOD OF LOGGING BOREHOLES. Patent No. 2,207,281, issued July 9, 1940, to Lawrence F. Athy and Harold R. Prescott, Ponca City, Okla., assignors to Continental Oil Company, Ponca City, Okla., a corporation of Delaware.

METHOD AND APPARATUS FOR PLACING A FILTER BODY IN A WELL. Patent No. 2,207,334, issued July 9, 1940, to John M. Reynolds, Wilmington, William M. Newton, Lomita, and Jerry T. Ledbetter, Compton, Calif., assignors to Union Oil Company of California, Los Angeles, Calif., a corporation of Calif.

MEANS AND METHOD OF CEMENTING WELLS. Patent No. 2,207,345, issued July 9, 1940, to Otto Hammer, Whittier, Calif., assignor to Security Engineering Co., Inc., Whittier, Calif., a corporation of California.

FILTER. Patent No. 2,207,346, issued July 9, 1940, to Basil Hopper, Palos Verdes Estates, Calif., assignor to Union Oil Company of California, Los Angeles, Calif., a corporation of California.

DETERMINATION OF THE CONNATE WATER CONTENT OF OIL PRODUCING FORMATIONS. Patent No. 2,207,348, issued July 9, 1940, to Philip H. Jones, Redondo Beach, and Arthur L. Blount, Palos Verdes Estates, Calif., assignors to Union Oil Co. of California, Los Angeles, Calif., a corporation of Calif.

APPARATUS FOR SPRAYING AND CASING WELLS. Patent No. 2,207,478, issued July 9, 1940, to Earl Russell Cameron, Sr., Charleston, W. Va.

DRILL PIPE ORIENTING TOOL. Patent No. 2,207,505, issued July 9, 1940, to Carl St. J. Bremner, Santa Barbara, and Charles M. Potter, Glendale, Calif.

OIL WELL FISHING TOOL. Patent No. 2,207,649, issued July 9, 1940, to John Huey Williams and Simeon Ackal, New Iberia, La.

TREATMENT OF WELLS. Patent No. 2,207,733, issued July 16, 1940, to Dana G. Hefley and John B. Stone, Tulsa, Okla., assignors to The Dow Chemical Co., Midland, Mich., a corporation of Michigan.

ROTARY DRILL BIT. Patent No. 2,207,766, issued July 16, 1940, to Lonnie L. Thompson, Iowa Park, Tex.

EXPANDING FOOT PIECE FOR WHIPSTOCKS. Patent No. 2,207,920, issued July 16, 1940, to James D. Hughes, Dallas, Tex., assignor of one-half to Eastman Oil Well Survey Corporation of California and one-half to Eastman Oil Well Survey Co. of Delaware.

PUMPING WELL HOOK-OFF DEVICE. Patent No. 2,207,937, issued July 16, 1940, to James P. Neel, Valley Center, Kans.

INSIDE TUBING CUTTER. Patent No. 2,208,011, issued July 16, 1940, to Ernest E. Anderson, Oklahoma City, Okla., assignor to Baash-Ross Tool Co., Los Angeles, Calif., a corporation of Calif.

WELL FLOWING APPARATUS AND METHOD. Patent No. 2,208,036, issued July 16, 1940, to Robert R. Kyner, Dallas, Tex., assignor, by mesne assignments, to Thomas E. Bryan, Fort Worth, Tex.

ELECTRIC HEATER (for oil wells). Patent No. 2,208,087, issued July 16, 1940, to Carlton J. Somers, Osage, Wyo.

PLACER CONCENTRATOR. Patent No. 2,208,092, issued July 16, 1940, to Charles N. Addis, Los Angeles, Calif., assignor of one-half to William Hattich, Los Angeles, Calif.

PNEUMATIC DISPLACEMENT PUMP. Patent No. 2,208,193, issued July 16, 1940, to James O. McMillan, Wichita, Kansas, assignor of one-fourth to A. G. W. Biddle, Skiatook, Okla.

SAFETY CAGE FOR OIL DERRICKS. Patent No. 2,208,194, issued July 16, 1940, to Nay Miles, Anahuac, Tex., assignor of one-third to Guy C. Jackson, Jr., and one-third to H. L. D. Scott, both of Anahuac, Tex.

OIL TOOL SPINNER. Patent No. 2,208,388, issued July 16, 1940, to Guy R. Pothe, Fullerton, Calif.

EXPANSIBLE AND CONTRACTIBLE ROCK DRILL. Patent No. 2,208,457, issued July 16, 1940, to Walter G. Hurley, East St. Louis, Ill., assignor of one-half to Lester A. Crancer, Webster Groves, Mo., and one-half to George B. Fleischman, University City, Mo.

GEOPHYSICAL *News and Review*

Compiled by the Geophysics Department, Colorado School of Mines

JOHNSON, C. H. *Steady State Polar Sensitivity Curves;* Geophysics 4(1), 33-52; Jan., 1939.

The paper treats the case of a steady state sinusoidal wave arriving at a horizontal line of uniformly spaced geophones whose outputs are to be added. The author first derives the equations for the cumulated amplitude as a function of the number of geophones and as a function of the phase difference between waves produced by extreme geophones and graphs thereof are discussed. The resultant or cumulated amplitude of the combined output of a geophone group is set up as a function of the difference in arrival time, at the end geophones and the period of the waves being parameters. This amplitude when plotted as a function of the time difference, noted above, shows principal and secondary maxima; the amplitudes, separation and sharpness thereof are discussed.

The second part of the paper considers the cumulated amplitude plotted as a function of the angle of arrival of the wave striking the geophones. These graphs are called polar sensitivity curves and illustrate the relative response of the group of connected geophones to waves coming from different directions. The effect of changes in the number of geophones, their spread, and the wave length on these curves is considered.

In the third part of the paper the "Sonograph" process is discussed in which the outputs of individual geophones are recorded as reproducible sound tracks and later cumulated after introducing equal phase differences between reproduction points on adjacent tracks. This varies the direction of maximum response being called "variable compounding" and permits the response of a geophone group to be focused to emphasize waves arriving from a given direction.

It is brought out in the summary that: 1. Many undesirable disturbances on reflection records come from a number of regular waves arriving at the geophones from different directions. 2. Directional selectivity to eliminate many of these undesired waves may be obtained by connecting several equally spaced geophones. 3. The conclusions of the paper based on steady state sinusoidal waves need only be modified quantitatively for other wave shapes. A list of 10 references is given. 4. Maximum discrimination in favor of waves having zero step out is obtained by connecting two spaced geophones together. 5. Maximum discrimination in favor of waves arriving perpendicular to the line of geophones comes from connecting together as large a number, *N*, of geophones as convenient and arranging their spread equal to $(N-1)^2/N$ times the effective wave length.

An abstract because of limitations of space cannot touch numerous other interesting phases of the subject treated.

—D. W.

KELLY, D. *A Reaction Type Shaking Table;* Geophysics 4(1), 69-75; Jan., 1939.

The article covers the basic design, design details and application of a steady state shaking table developed for measurement of the response of seismometers and the over all response of seismograph equipment including filters, amplifiers and recorders. The table described has constant output of displacement, velocity or acceleration, over the working range of frequency; is unaffected by the apparatus which it drives; has signal level control and a variable control of signal frequency. In addition it gives a signal in which harmonic distortion of wave form is negligible.

In the instrument which is shown in photographs a 500 lb. mass, suspended on springs, is vibrated at amplitudes of some 10^{-4} inches by a small electric motor driven eccentric mass rotated at the center of percussion of a small pendulum or bar, the upper end of which is pivoted to the bottom of the heavy mass. Horizontal motion is very largely eliminated by the pendulum bar which does not transmit horizontal force through its axis. The amplitude of the motion of the top of the table is independent of frequency between 10 cycles per sec. to above 150 cycles per sec.

The table produces constant amplitude sinusoidal displacements. A graph of over-all frequency response from 10 to 90 cycles per sec. is given. Tests indicate the table is nearly as rapid in use in determining frequency response of the electromechanical systems used in seismic prospecting as the ordinary electrical signal generator is in determining the response of purely electrical networks.

—D. W.

SPARKS, N. R. AND HAWLEY, P. F. *Maximum Electromagnetic Damping of a Reluctance Seismometer;* Geophysics 4(1), 1-7; Jan., 1939.

The writers note that the response of an electromagnetically damped reluctance type seismometer is expressed by a third order differential equation. Such equations can only be solved explicitly in special cases. The mathematical expression for the oil damped seismometer is, by way of comparison, a simple second order differential equation which has been completely discussed elsewhere.

An explicit solution for the equation of motion for the electromagnetically damped seismometer for the case of greatest interest, namely for maximum damping, is given. This yields the relations of the seismometer constants of mass, spring, and damping resistor for this case.

A graph shows observed and theoretical response for a balanced armature type reluctance seismometer to a unit function force. The mathematical treatment presented applied only to an ideal seismometer which, the authors suggest, make the results a qualitative guide to seismometer performance.

It appears that the ultimate value of damping obtainable electromagnetically is such that the seismometer becomes unstable because the pole pieces tend to stick. The actual ultimate value that can be obtained is therefore determined by the stability required. Critical damping, ordinarily used in seismometers is obtained electromagnetically as shown by the mathematical development when the "negative equivalent spring constant due to unbalanced magnetic pull of the armature" is greater than 90% of the "spring constant."—D. W.

COWLES, L. *The Adjustment of Misclosures.* Geophysics 3(4), 332-339, October, 1938.

A method is presented for the adjustment of misclosures of a geophysical survey by using measurements of current in an electrical resistance network. Adjustments of measured data in a survey are as a rule necessary to absorb the observed misclosures which is usually accomplished by applying the method of least squares. This necessitates the rather laborious process of writing and solving a system of simultaneous equations obtained from an inspection of the traverse results.

The paper explains the mathematics of least square adjustment of survey misclosures and develops the electrical analogy by the use of which considerable time can be saved in solving the equations set up. To accomplish this, currents are measured in an electrical network analagous to the survey involved in which the resistances are proportional to the segments of the survey, voltages applied in each loop being equal to the misclosure in a loop. The currents are proportional to the unknown, and sought multiplying factors (K), in the simultaneous equations of the least square adjustment. The application of the procedure to closing dip shooting traverses, or lines, in seismic reflection surveys is brought out.—D. W.

ELKINS, T. A. AND HAMMER, S. *The Resolution of Combined Effects, with Applications to Gravitational and Magnetic Data.* Geophysics 3(4), 315-331, October, 1938.

The author sets forth the mathematics of a method for determining the minimum separation of two nearby subsurface bodies, at which their observed combined effect indicates the presence of the two as separate bodies.

Two masses, or magnetic bodies of similar shape and size, may be located below the surface so close together that a survey across them by the torsion balance or the magnetometer produces an anomaly curve that may appear to arise from one subsurface body.

The minimum separation of two such bodies, of assumed shape, size and depth, at which the presence of two masses will be visible from survey results, called the resolution limit, is examined. The cases for two identical spheres and two infinite horizontal cylinders as revealed by gravity and its derivatives and for the same objects by torsion balance traverses are treated. The situation on a like basis for two rectangular plugs by magnetic vertical intensity and the use of the resolution limit as an aid in the interpretation of the case of an infinite horizontal block are covered.

The usefulness of the analysis in establishing the proper station spacing for a particular method used and in determining the suitability of a geophysical method in a given case is brought out.

—D. W.

GEOPHYSICAL *News and Review*

Compiled by the Geophysics Department, Colorado School of Mines

JOHNSON, C. H. *Steady State Polar Sensitivity Curves;* Geophysics 4(1), 33-52; Jan., 1939.

The paper treats the case of a steady state sinusoidal wave arriving at a horizontal line of uniformly spaced geophones whose outputs are to be added. The author first derives the equations for the cumulated amplitude as a function of the number of geophones and as a function of the phase difference between waves produced by extreme geophones and graphs thereof are discussed. The resultant or cumulated amplitude of the combined output of a geophone group is set up as a function of the difference in arrival time, at the end geophones and the period of the waves being parameters. This amplitude when plotted as a function of the time difference, noted above, shows principal and secondary maxima; the amplitudes, separation and sharpness thereof are discussed.

The second part of the paper considers the cumulated amplitude plotted as a function of the angle of arrival of the wave striking the geophones. These graphs are called polar sensitivity curves and illustrate the relative response of the group of connected geophones to waves coming from different directions. The effect of changes in the number of geophones, their spread, and the wave length on these curves is considered.

In the third part of the paper the "Sonograph" process is discussed in which the outputs of individual geophones are recorded as reproducible sound tracks and later cumulated after introducing equal phase differences between reproduction points on adjacent tracks. This varies the direction of maximum response being called "variable compounding" and permits the response of a geophone group to be focused to emphasize waves arriving from a given direction.

It is brought out in the summary that: 1. Many undesirable disturbances on reflection records come from a number of regular waves arriving at the geophones from different directions. 2. Directional selectivity to eliminate many of these undesired waves may be obtained by connecting several equally spaced geophones. 3. The conclusions of the paper based on steady state sinusoidal waves need only be modified quantitatively for other wave shapes. A list of 10 references is given. 4. Maximum discrimination in favor of waves having zero step out is obtained by connecting two spaced geophones together. 5. Maximum discrimination in favor of waves arriving perpendicular to the line of geophones comes from connecting together as large a number, N, of geophones as convenient and arranging their spread equal to $(N-1)^2/N$ times the effective wave length.

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—D. W.

KELLY, D. *A Reaction Type Shaking Table;* Geophysics 4(1), 69-75; Jan., 1939.

The article covers the basic design, design details and application of a steady state shaking table developed for measurement of the response of seismometers and the over all response of seismograph equipment including filters, amplifiers and recorders. The table described has constant output of displacement, velocity or acceleration, over the working range of frequency; is unaffected by the apparatus which it drives; has signal level control and a variable control of signal frequency. In addition it gives a signal in which harmonic distortion of wave form is negligible.

In the instrument which is shown in photographs a 500 lb. mass, suspended on springs, is vibrated at amplitudes of some 10^{-4} inches by a small electric motor driven eccentric mass rotated at the center of percussion of a small pendulum or bar, the upper end of which is pivoted to the bottom of the heavy mass. Horizontal motion is very largely eliminated by the pendulum bar which does not transmit horizontal force through its axis. The amplitude of the motion of the top of the table is independent of frequency between 10 cycles per sec. to above 150 cycles per sec.

The table produces constant amplitude sinusoidal displacements. A graph of over-all frequency response from 10 to 90 cycles per sec. is given. Tests indicate the table is nearly as rapid in use in determining frequency response of the electromechanical systems used in seismic prospecting as the ordinary electrical signal generator is in determining the response of purely electrical networks.

—D. W.

SPARKS, N. R. AND HAWLEY, P. F. *Maximum Electromagnetic Damping of a Reluctance Seismometer;* Geophysics 4(1), 1-7; Jan., 1939.

The writers note that the response of an electromagnetically damped reluctance type seismometer is expressed by a third order differential equation. Such equations can only be solved explicitly in special cases. The mathematical expression for the oil damped seismometer is, by way of comparison, a simple second order differential equation which has been completely discussed elsewhere.

An explicit solution for the equation of motion for the electromagnetically damped seismometer for the case of greatest interest, namely for maximum damping, is given. This yields the relations of the seismometer constants of mass, spring, and damping resistor for this case.

A graph shows observed and theoretical response for a balanced armature type reluctance seismometer to a unit function force. The mathematical treatment presented applied only to an ideal seismometer which, the authors suggest, make the results a qualitative guide to seismometer performance.

It appears that the ultimate value of damping obtainable electromagnetically is such that the seismometer becomes unstable because the pole pieces tend to stick. The actual ultimate value that can be obtained is therefore determined by the stability required. Critical damping, ordinarily used in seismometers is obtained electromagnetically as shown by the mathematical development when the "negative equivalent spring constant due to unbalanced magnetic pull of the armature" is greater than 90% of the "spring constant."—D. W.

COWLES, L. *The Adjustment of Misclosures.* Geophysics 3(4), 332-339, October, 1938.

A method is presented for the adjustment of misclosures of a geophysical survey by using measurements of current in an electrical resistance network. Adjustments of measured data in a survey are as a rule necessary to absorb the observed misclosures which is usually accomplished by applying the method of least squares. This necessitates the rather laborious process of writing and solving a system of simultaneous equations obtained from an inspection of the traverse results.

The paper explains the mathematics of least square adjustment of survey misclosures and develops the electrical analogy by the use of which considerable time can be saved in solving the equations set up. To accomplish this, currents are measured in an electrical network analagous to the survey involved in which the resistances are proportional to the segments of the survey, voltages applied in each loop being equal to the misclosure in a loop. The currents are proportional to the unknown, and sought multiplying factors (K), in the simultaneous equations of the least square adjustment. The application of the procedure to closing dip shooting traverses, or lines, in seismic reflection surveys is brought out.—D. W.

ELKINS, T. A. AND HAMMER, S. *The Resolution of Combined Effects, with Applications to Gravitational and Magnetic Data.* Geophysics 3(4), 315-331, October, 1938.

The author sets forth the mathematics of a method for determining the minimum separation of two nearby subsurface bodies, at which their observed combined effect indicates the presence of the two as separate bodies.

Two masses, or magnetic bodies of similar shape and size, may be located below the surface so close together that a survey across them by the torsion balance or the magnetometer produces an anomaly curve that may appear to arise from one subsurface body.

The minimum separation of two such bodies, of assumed shape, size and depth, at which the presence of two masses will be visible from survey results, called the resolution limit, is examined. The cases for two identical spheres and two infinite horizontal cylinders as revealed by gravity and its derivatives and for the same objects by torsion balance traverses are treated. The situation on a like basis for two rectangular plugs by magnetic vertical intensity and the use of the resolution limit as an aid in the interpretation of the case of an infinite horizontal block are covered.

The usefulness of the analysis in establishing the proper station spacing for a particular method used and in determining the suitability of a geophysical method in a given case is brought out.

—D. W.

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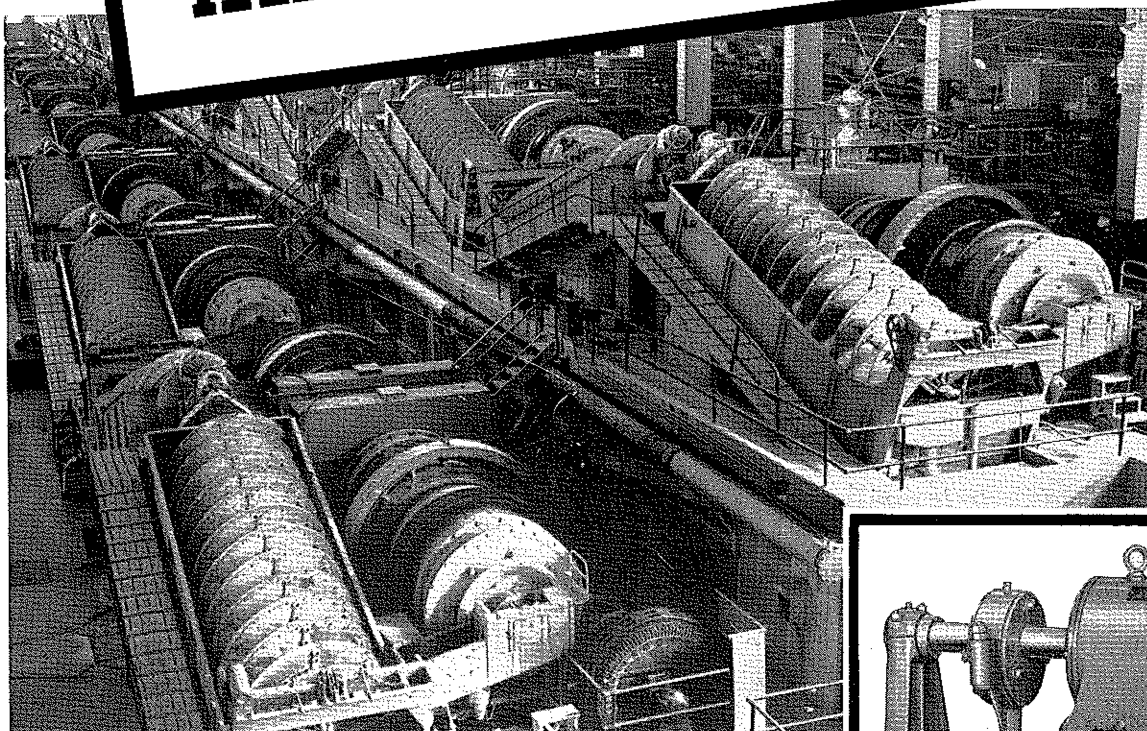

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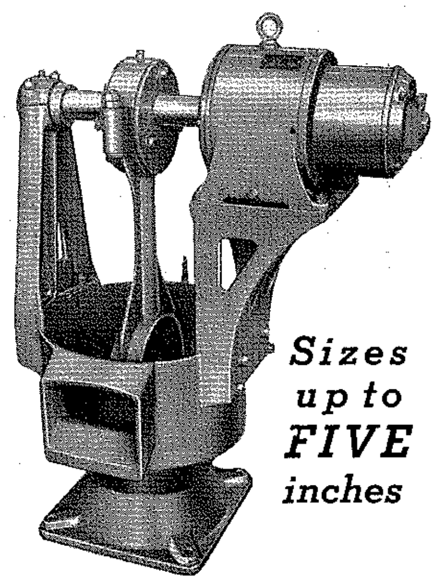

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