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Research Council of Alberta

Thirty-sixth Annual Report

1955

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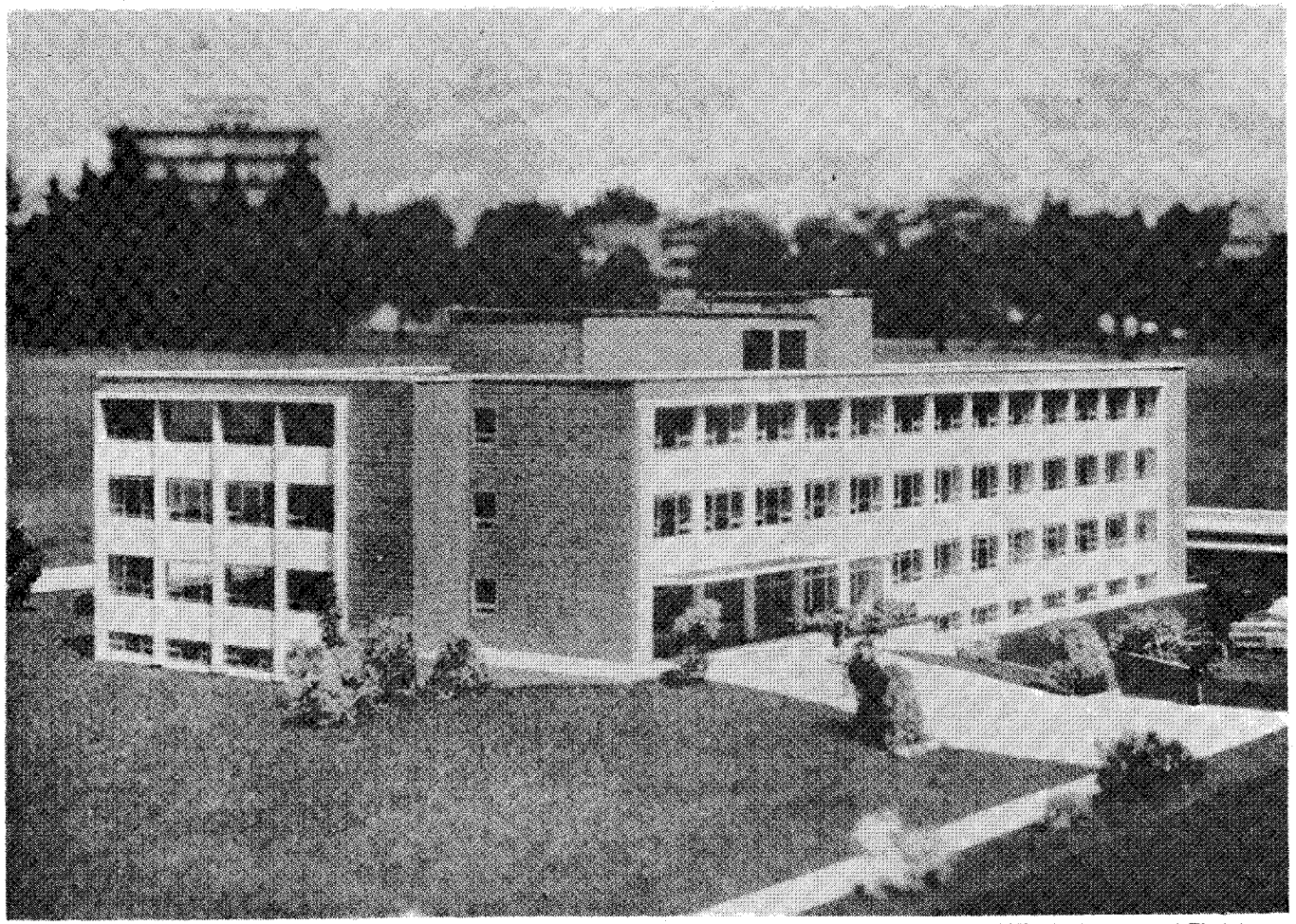

(Alberta Government Photo)

New Research Council Building.

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FOREWORD

The following report, the Thirty-sixth Annual Report of the Research Council of Alberta, was submitted in February 1956, by Dr. N. H. Grace, Director of Research, to the Chairman of the Council, the Honourable G. E. Taylor, Minister of Highways and Minister of Telephones. The Chairman submitted the report to the Premier of Alberta, the Honourable E. C. Manning, who tabled it in the Legislature.

Council administration, laboratories and pilot plant are situated at 87th Avenue and 114th Street. The soils and natural gas sections are located in the Agricultural and Engineering Buildings of the University of Alberta, respectively. Requests for information should be addressed to the Secretary, Research Council of Alberta, University of Alberta, Edmonton, Canada.

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The Council operates under the Research Council Act of 1930 as amended 1943, 1945, 1950 and 1955.

ANNUAL REPORT

1955

The work of Council for the calendar year 1955 is described in this report. The Research Council is responsible for the obtaining of scientific information basic to the effective development of the natural resources of Alberta. Increased emphasis this year has been placed on basic geological research and survey since geological information bears directly on much of the province's resources. The over-all research program has included soil surveys and classification, irrigation research and studies on fuels, the latter both applied and fundamental in nature. Specific fuel projects were coal, natural gas and petroleum, including work on the Athabasca oil-sands oil. The Industrial Engineering Services section has provided technical information and advice to the industries of the province, and effective service has been rendered by the Gasoline and Oil Testing Laboratory. An *ad hoc* committee has given some attention to the hail problem.

The year has been marked by generally satisfactory progress in all projects. Certain appointments could not be made until the building was completed and this delayed the expected development of some of the projects, in particular pilot plant operations on applied problems. Only part of the staff was able to move into the nearly completed new building late in the year. This perhaps can be described as a year of transition in Council operations, with all efforts striving towards effective consolidation and integration of effort in the fine, new, modern research laboratories and pilot plant into which most of Council's operations will be concentrated early in 1956.

The research program on coal stressed basic studies on coal constitution, bearing on the development of alternative utilization schemes for this important fossil fuel. Physical investigations included continuation of the study of coal-solvent behavior in an ultrasonic field and demonstrated that the "true" density of coal appears to remain substantially unaffected but that coal surface area tends to increase with the frequency of vibration and length of time of exposure; preliminary carbonization tests demonstrated that significant modifications in the nature of the tar can be induced by the presence of traces of nitric oxide in the retort. The organic chemical approach by a combination of infrared spectra and elementary analyses indicated the relationship between humic acids and coals of various ranks; oxidation of phenols has revealed that oxidative polymerization of completely aromatic materials can result in the production of naphthenic structures known to occur in coal and petroleum; polarographic studies have shown that humic acids from hydroquinone and low-rank coal appear to have less condensed structures than humic acids from higher-rank material; cracking catalysts in coal carbonization were shown to affect the primary decomposition processes of the coal as well as the secondary decomposition of the primary tar. Paleobotanical studies included two major collections—one stratigraphic and the other taxonomic—of coal, shale, and fossilized woods from twenty-one horizons; these will serve as foundations for correlating spores and pollen grains with geological horizons and are the basis of a two-pronged attack on the problem of floral sequence in the Upper Cretaceous and Lower Tertiary formations. Analytical

testing of coal was continued; development of standard methods for determination of the 'capacity moisture content' and 'volatile matter content' of coal was under study; progress was made in the design of a laboratory instrument capable of measuring the pressures exerted by coking coals during carbonization. Applied studies included continuation of surface treatment to reduce disintegration of subbituminous coals during storage and on coal grindability, and a co-operative research program on coal cleaning and briquetting has been arranged.

. Petroleum research—formerly described as oil-sands research—continues, through investigation of the trace metals and porphyrin contents of oils, to throw light on the geological age, migration and accumulation of natural oil. Temperature, bacterial action, and catalysis are among the recognized factors responsible for the maturation of organic material to petroleum. The McMurray oil is high in trace metals, has low gravity, and apparently is a young crude oil. The kinetics of thermal degradation or maturation for removal of vanadium or nickel from McMurray oil proved both these reactions to be of first order, at 350°C. the rates being about 0.01/hr. with activation energies of about 56 Kcal./mole. Similar, but higher, reaction rates were obtained for magnesium and porphyrin. Quantitative examination of the several reactions suggests that geological time has been too short to account for the observed maturation of crude oils in Alberta at temperatures regarded as likely during geological time, and it seems probable that stress must be laid on the importance of catalysis in the formation of crude oil as it is found. In other investigations on the storage and handling of heavy crude oils the characteristics of oil-water emulsions with suspended sand particles were determined. Detailed investigations were made of the sulfur content of heavy oils using chromatography on distillate fractions. It was found that sulfur extraction methods were not satisfactory and consequently desulfurization studies are being made through catalytic decomposition and oxidation processes.

The natural gas research program continued work on the partial oxidation of butane, and results indicate that the reaction is essentially that of "cold flame", characterized by a pronounced induction period, sharp reaction peak and self-quenching termination; investigation of the permeable tube technique for the production of carbon black has been completed; preliminary studies on the high temperature pyrolysis of butane show that lower partial pressures favor formation of ethylene and higher pressures favor acetylene.

Geological study in the oil-sands area has been completed by surveys along the Firebag and Clearwater rivers from the eastern boundary of Alberta to the Athabasca river; heavy oil was found in fractured Devonian limestone in township 97, range 7, west of the Fourth Meridian; a full report and map are in preparation for publication. An expanded glacial geology survey program completed mapping in the Alliance-Brownfield and Castor districts. An extensive drilling project indicated that, for the most part, the glacial materials are quite thin, generally under 25 feet, and overlie the Edmonton and Bearpaw formations; as a result, most of the groundwater in this area is taken from bedrock. Results of laboratory studies on the base-exchange characteristics of colloidal-size quartz are proving helpful in interpreting the base-exchange of soils with a high quartz content in the clay size. A groundwater survey is making an assay of Alberta's groundwater potential, matched against present and future demand from rural settlement, municipalities and industries. Micropaleontological research has dealt with the establishment of microfaunal zones in the Cenomanian and Turonian stages of the Upper

Cretaceous, the calibration of these zones with megafaunal sequences and their subsequent correlation with sections in distant areas, the formal description of the commonly occurring species of Formanifera and ecological considerations. Clays separated from older sediments in a section across the Oldman-Bearpaw contact are being subjected to chemical and mineralogical analyses; core samples from the oolitic iron deposit in the Peace River area have been taken at intervals and these samples are being checked for insoluble content and thin-section analysis; microfossils are being separated from the shale fractions for dating purposes.

Council soil surveyors completed the reconnaissance survey of the Beaverlodge sheet and did final pre-publication checking of the Grande Prairie-Sturgeon Lake area. An exploratory soil survey by helicopter (the first such soil survey in Canada, it is believed) covered an area of some 16,500 square miles. The co-operative irrigation research project on solonetzic soil was continued and further data were obtained on the effects of soil amendments, cultural and legume treatment on the physical structure and productivity of such soils under irrigation and dry conditions; certain of the amendments and cultural treatments demonstrated appreciable increase in the yields from test plots of sweet clover, wheat and oats; penetrometer readings demonstrated significant changes in soil structure due to cultural treatment.

The Industrial Engineering Services section provided technical information to rapidly developing Alberta industry through individual plant calls, to government departments, and to the public. This group is establishing a ceramics laboratory for research and testing purposes; research of an engineering nature has been commenced on butane; special tests or investigations may be undertaken on behalf of industry.

General testing and analytical service is provided to industry, Provincial Government departments, the Department of National Defence, and the public by Council's Gasoline and Oil Testing Laboratory; the research projects of this group include a long-term investigation of the deterioration of aviation gasoline on storage.

The Highway Research program conducted winter field trials to confirm results of laboratory tests on prevention of frost heaving in soils by injection of lignosol and lignosol-chromate mixtures. It was found that the highly mechanized procedure developed was not as efficient as anticipated and that the designed proportions of lignosol and chromate did not set up in the field as successfully as under laboratory conditions; subsequently it was found that the temperature of the chrome-lignosol solution markedly affects setting rate. In the study of the movement of chemical solutions through soils by the process of electroosmosis, it was found that the addition of lignosol permitted solutions to be moved through coarse sands; basic data of a fundamental nature have been secured on the electrical permeability of coarse sands and silts.

The Biological Cycles project indicated a continued paucity of the cyclic animal population through central and northern Alberta, but careful census of selected locations showed that there has been an increase in population, with the highest population found in the southeastern part of the province. Solar ultraviolet radiation measurements have been continued; additional equipment is helping to tie together European and American measurements.

Work on the "Hatchability of Turkey Eggs", carried on at the University of Alberta and supported by Council, demonstrated that use of upstanding

males in the breeding pens resulted in improved fertility of eggs as compared with performance from pens in which front-heavy toms were used; certain known vitamins and unidentified factors apparently had no observable effect on reproductive performance.

The various research programs of Council have been aided through the co-operation of the University of Alberta, Provincial Government departments, the National Research Council, the Department of Mines and Technical Surveys, and the Dominion Experimental Farms Service. The helpful services of Council's advisory committees have contributed greatly to the progress of all research projects. Special mention is made of the contribution of the Department of Public Works of Alberta in the design and construction of the fine new laboratories and pilot plant into which Council's staff were moving at the end of the year.

COAL

The reorientation of Council's coal research program, to which reference was made in the Annual Reports of 1953 and 1954, has now been completed, and the past year has seen encouraging progress along the new lines. Several applied research projects have had to be curtailed or held in abeyance until the space and facilities of the new pilot plant are available. But laboratory investigations have benefited greatly from the provision of new or improved equipment, and most of these investigations have been considerably intensified and accelerated.

Analytical Laboratory

The major program of the analytical laboratory consisted in routine analysis of coal samples submitted by the Provincial Mines Branch, by the Department of National Defence, and by various coal operators. In addition, the laboratory has undertaken the analysis of coal and coal derivatives submitted by other sections of the coal division, and has been responsible for a considerable volume of work on infrared spectroscopy that has been occasioned by the several investigations into coal constitution and pyrolysis.

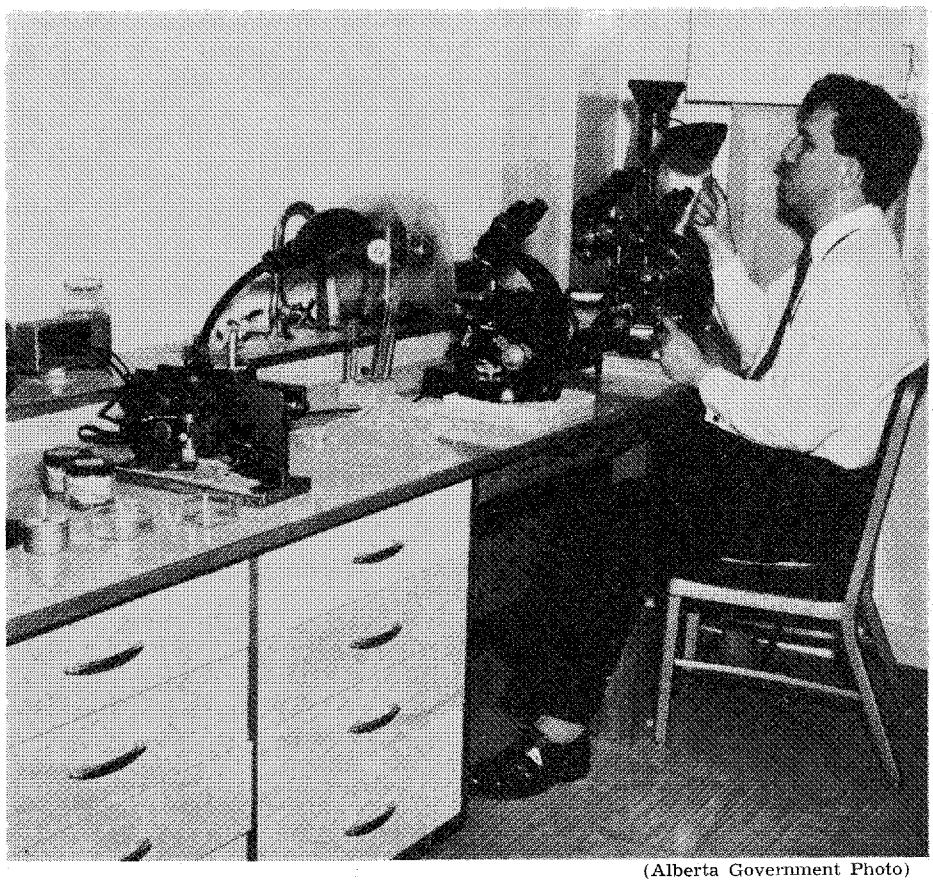
Moreover, much work has been carried out in connection with the development of standard methods for the determination of the 'capacity moisture content' and 'volatile matter content' of coal. Possible standard methods have been under advisement by the International Standards Organization and the American Society for Testing Materials for some time. Council has representation on both of these organizations and several of its recommendations have been incorporated into the tentative standard method for determining 'capacity moisture'. A current study of techniques for determining the 'volatile matter content'—involving investigation of three analytical procedures and six coals of different rank—is nearing completion, and it is hoped to communicate the results of this work to Subcommittee XXI of Committee D5 (Coal and Coke) of the ASTM in February 1956.

The analytical laboratory has also worked on the designing of a laboratory instrument capable of measuring the pressures exerted by coking coals during carbonization.

Paleobotanical Laboratory

The operations of the Paleobotanical Laboratory have been expanded by the appointment of a full-time assistant and by the acquisition of several pieces of optical and microtechnical equipment.

The most important work of the laboratory during 1955 has concerned itself with the endeavor to establish a standard geological column in the Cretaceous and Tertiary coal-bearing horizons of the province. The Petroleum and Natural Gas Conservation Board of Alberta co-operated generously in this effort by supplying three series of well-cutting samples, each from a wildcat well in the general region of the new Pembina oil field. These samples, and the electro-log graphs accompanying them, provide a record of the 3,000 or 4,000 feet of sedimentary rocks overlying the Belly River formation in this area—that is, of the Paskapoo (Tertiary) and Edmonton (Upper Cretaceous) formations. It is interesting to notice that the electro-logs indicate that these upper formations in the Pembina region contain at least 100 or 200 feet of coal.



(Alberta Government Photo)

The microscope—the essential tool of paleobotany.

However, because subsurface collecting methods are subject to considerable errors and uncertainties, a more reliable series of samples was collected in the "Badlands" of the Red Deer river. The "Badlands", an extensive canyon system, cut nearly two hundred miles across the plains from Red Deer city in the northwest, the site of one of the most extensive of all exposures of the Paskapoo formation, downstream through the excellent outcrops of the Edmonton formation at Drumheller, to Steveville in the southeast where the Belly River formation dominates. The exposed geological section is

unsurpassed, being almost complete from Paskapoo to Belly River, and its stratigraphy is well-known. Collection in this area yielded an assemblage of stratigraphically identified specimens, including about thirty-five coal and forty-five shale samples, with which to study the sequence of plant microfossils through the uppermost Cretaceous and Tertiary, and a small group of animal fossils for correlation. In addition, the collection included over a hundred specimens of fossilized wood from twenty-one horizons in the region.

Fossilized wood, almost wholly derived from coniferous trees, is probably the commonest type of fossil in the formations under study, both in the Red Deer Badlands and elsewhere in the province, and these facts have prompted a concurrent study of the wood of living conifers, especially of the numerous rarer subtropical and Southern Hemisphere genera, in order to derive a workable scheme for identifying the Alberta fossils and fossil-horizons. Samples were requested from a number of botanical gardens and universities in the regions of the world where conifer genera are most numerous, particularly in East Asia, New Zealand-Australasia, South America and the Mediterranean regions, as well as in Pacific North America. Several of these institutions have responded very generously so that Council now possesses a collection of woods, twigs, foliage, and seeds representing forty-three of the fifty-two genera of conifers, and a good variety of species from such diversified genera as *Pinus* of the Northern Hemisphere and *Podocarpus* of the Southern. The collection includes the aberrant "living fossil" genus *Ginkgo,* all nine genera of the Pine family, both Araucarian genera, all ten of the Bald-cypress or *Sequoia* family, thirteen of the seventeen genera of the true Cypresses, six of the seven Podocarps, and two of the six yews. Of the remaining nine genera, seven are so rare and circumscribed in their ranges that they are probably quite impossible to obtain.

These two major collections—the one stratigraphic and the other taxonomic —will now serve as foundations, the first for correlating spores and pollen grains with geological horizons, and the second for correlating the woods. They are thus the basis of a two-pronged attack on the problem of floral sequence in the Upper Cretaceous and Lower Tertiary formations.

Physical Chemistry Laboratory

Work has been largely concentrated upon two programs that were initiated during 1954. Both are directed towards further exploration of the chemical potential of coal and towards an elucidation of its properties and structure.

The first of these programs, an investigation of the physical behavior of coal in ultrasonic fields, arose from the preliminary results given in the Annual Report for 1954. It was there shown that while ultrasonic vibrations in the frequency range 1—2 mc./sec. increased the rate of extraction of coal by methanol, the total yield of extract was not significantly increased by such vibrations. Before undertaking similar experiments with other solvents and under different experimental conditions, it was thought desirable to investigate the effect of ultrasonic fields upon the coal *per se,* and to examine, in particular, possible changes induced in the colloid structure of typical coals, in their densities, and in their 'crystalline' structure. This work is still in progress, but the results already available are sufficiently extensive to permit several important conclusions to be formulated. Over the frequency range examined so far (250 kc./sec. to 1 mc./sec.), the 'true' density of coal appears to remain substantially unaffected by ultrasonic vibrations. However, very significant changes have been observed in the accessible surface area (as

determined by the heat-of-wetting method) and in the 'crystallinity' of coal. The surface area tends to increase both with the frequency of vibration and the length of time for which the coal is exposed to such vibrations, and the actual increases may be large. It is possible that such increases, which are believed to arise from an opening of an existing pore structure in the coal rather than from the creation of new surface, are in themselves sufficient to account for the increased extraction rates previously observed. A theoretically significant observation is the fact that ultrasonic vibrations do not affect the interplanar spacings of the coal crystallites. For the one (low-rank) coal so far studied, this spacing remained constant at about 4.35 A; while the crystallites may legitimately be assumed to consist of essentially coplanar molecules, they can therefore not be supposed to be graphitic.

In connection with the studies described above, an attempt has also been made to estimate what fraction of the total ultrasonic energy theoretically available to the coal is actually 'absorbed' by it and utilized for physical and/or chemical changes. A calorimetric technique developed for this purpose gave results that suggested some 99 per cent of the input energy either to 'bypass' the coal entirely or to be elastically reflected by it. In the simple system used for the current experiments—in which ground coal is suspended in a neutral carrier liquid (0.25 per cent aqueous aerosol) and exposed to the ultrasonic vibrations—the efficiency of irradiation is extremely low. Efforts are now being made to increase this efficiency by incorporating suitable reflectors in the reaction chamber.

The second program of investigation was the carbonization study to which reference was made in the Report for 1954. Following a number of preliminary carbonization tests in a 2-lb. stainless steel, vertical, electrically-heated retort (and characterization of the tars thus obtained by fractional distillation and infrared spectroscopy), it could be demonstrated that significant modications in the nature of the tar can be induced by the presence of traces of nitric oxide in the retort. Retardation of the decomposition of the coal as well as of secondary (tar-phase) condensation reactions has been observed. Detailed study of the resultant tars and of the infrared spectra of various tar fractions has, however, shown that inhibition of secondary condensation is only a temporary effect. A reaction mechanism, postulating transient attachment of nitric oxide to the tar molecules, has therefore been postulated. It was also established that tars modified by nitric oxide will condense in the presence of white light and that this reaction, which proceeds as fast as in the case of 'normal' tars, does not require the presence of oxygen.

Current experiments are endeavoring to find more efficient modifiers than nitric oxide, and an attempt is being made to examine these by carbonization tests as well as by differential thermal analysis. A suitable D.T.A. assembly has already been built and is presently under test.

Organic Chemistry Laboratory

Investigations into coal constitution and the structure of humic acids have continued to form the major program of the laboratory.

Coal chemistry has been difficult to elucidate because by their very nature these materials cannot be adequately characterized by classical organic procedures. By combining infrared spectra and elementary analyses, it is now possible to follow a number of operations in the chemistry of carbonized materials. These studies have served to show the relationship between humic

acids and coals of various ranks. By using new techniques and studying previously ignored absorption bands an additional parameter in the coalification series has been discovered. The spectra of humic acids derived by the oxidation of phenols have revealed the fact that oxidative polymerization of completely aromatic starting materials can result in the production of naphthenic structures known to occur in coal and petroleum.

By autoclaving cellulose in a series of experiments at different temperatures, chars are produced which on the basis of carbon and hydrogen analyses and infrared spectra show a close similarity with various ranks of coal. The hydrogen content of the chars tends to become constant at about 4.5 per cent over a considerable range of carbon content. The infrared spectra of the chars duplicate those of coal in surprising details such as the occurrence of a distinct 6.7 micron band only in the spectra of low-temperature chars and the appearance of the diagnostic bituminous coal bands in the long-wavelength region in the spectra of high-temperature chars.

Concurrently with the spectroscopic investigation, the functional group analyses and related studies on humic acids have been continued. Substances closely resembling lignin have been obtained from humic acids derived from hydroquinone, but the reactions used were less successful when applied to humic acids derived from coal, particularly higher-rank coal. Polarographic studies have shown that humic acids from hydroquinone and low-rank coal appear to have less condensed structures than humic acids from higher-rank material. These results are consistent with X-ray studies in other laboratories which have shown that humic acids derived from coals of increasing rank show increasingly graphitic structures.

In connection with the coal constitution studies, some work has also been carried out with pure compounds thought to have structures similar to those occurring in coal. One of these is truxene which, upon heating in the absence of air to a temperature above its melting point, 365°C., blackens and assumes some coal-like properties. It is, for example, no longer soluble in solvents that will dissolve truxene itself; it will no longer melt; and it is quite brittle. Both truxene and the product obtained on heating show infrared absorption bands at 6.2 microns, and the persistence of this band after heating suggests that the choice of truxene as a 'coal model' may not be entirely lacking in credibility. One postulate as to the manner in which truxene molecules polymerize to form the black polymer involves a fulvene-type of structure, and this aspect is now being examined by means of several, specially prepared fulvenes.

A second major program is concerned with the effect of cracking catalysts upon the course of coal carbonizations. Observations to date indicate that the presence of an alumina silicate catalyst in carbonizations carried out at 600°C. results in changes in the nature and yields of the products. The lowered decomposition point of the coal and the decreased coking tendencies of bituminous coals indicate that the catalyst is affecting the primary decomposition processes of the coal as well as the secondary decomposition of the primary tar. The markedly decreased coking tendency of the coal in the presence of catalysts also favors the conventional mechanism of coking which involves melting of at least part of the coal substance before gaseous evolution takes place.

Preliminary research toward the use of humic acids and low-grade coals as soil amending agents and viscosity stabilizers in drilling muds has been

carried out. However, these studies have been hampered by a lack of basic information on the nature of the interactions between humic acids and clay. Experimental work is planned to attempt to provide this information. Investigation of the mechanism of the concentration of uranium with coal by means of ion exchange chromatography has shown that this phenomenon involves the formation of metallo-organic complexes. Polarographic studies have confirmed the existence of such complexes between pyridine extracts of coal and uranyl ions.

Applied Research Laboratory

Awaiting completion of suitable space and facilities, projected pilot-plant studies on various aspects of coal cleaning and briquetting have been postponed for a year, and resumption of a stoker program and the initiation of a study of colloidal fuels proved impossible largely because of insufficient staff. Under these circumstances, the laboratory has confined itself to two more modest programs that arose partly from last year's activities and partly from foreseeable industrial needs.

The first of these was concerned with efforts to surface-seal Alberta subbituminous coals against loss of water and to prevent or reduce, by this means, the disintegration of such coals during storage. The general approach has followed closely upon that adopted in the dust-proofing program undertaken in 1954, and some success has been achieved by treating coal lumps with emulsions of wax, bitumen, heavy oils, etc. For example, a coal tending to lose some 15 per cent water within two weeks, lost only about 1 per cent after dipping in a wax-oil emulsion in water. Even more effective surface-sealing appears possible with bitumen, and current experiments are attempting not only to evaluate alternative sealing agents but also to test the merits of different techniques of surface-coating. Particular attention is being paid to the possibility of coating coal lumps by sprays and mists, and to the over-all economics of the various alternatives.

Substantial progress has also been made in a study of coal grindability which was initiated towards the end of 1954. Based upon the view that a more complete knowledge of coal behavior during grinding operations is desirable because of the increasing demand for pulverized fuel, this investigation is directed towards elucidating factors determining 'grindability' and towards estimating power consumption during grinding of the various types of coal. A laboratory roll-crusher has been designed and built, and this instrument has been used to establish the effect on grindability, of coal rank and physical characteristics, of the size composition of the coal, of the rate of feeding, of the rotational velocity of the rolls, and of the gap-size. Attempts are now being made to assess these various factors in the light of the standard Hardgrove test (which is itself regarded as somewhat unsatisfactory when used in conjunction with low-rank coals). The ultimate aim of the investigation, the measurement of net grinding energy, is now being approached; a motor assemblage capable of operating the crusher-rolls in such a way as to enable direct determination of the torque on the rolls is now under construction and is expected to come into operation within a few weeks.

A research program, concerned with a preliminary but nevertheless detailed study of coal fluidization, is being carried out under Council's auspices in the Department of Chemical Engineering, University of Alberta, as a post-graduate investigation. A small fluid carbonizer, with a capacity of 50 lbs.

per hour, has been built and operated for a period of several weeks, and valuable information on the effect of coal type and sizing on the dynamics of fluid beds has been obtained. It is expected that this equipment will yield sufficient data to permit the construction of a large-scale fluidized carbonizer toward the end of 1956.

Arrangements have also been completed for a co-operative research program on coal cleaning and briquetting. This work will be carried out jointly by the Research Council of Alberta and the Federal Mines Branch team stationed in Edmonton, in the new pilot plant.

Mention may be made of the role played by Council in establishing, together with the Coal Operators' Association of Western Canada, The Western Coal Utilization Council. The objectives of this organization are the maintenance and expansion of markets for all types of coal by the provision of technical and marketing information to coal operators, coal dealers, industrial coal consumers and equipment manufacturers. Participating agencies are the Alberta Reclamation Association, the Bituminous Section of the Coal Operators' Association of Western Canada, the Domestic Section of the Coal Operators' Association of Western Canada and the Research Council of Alberta. Administrative control is vested in a committee comprising two members from each of the participating agencies, together with an appointed Secretary-Treasurer. An Executive Committee, on which the Research Council is represented, is responsible for general supervision of the project and for direction of the field staff.

Miscellaneous

Members of the coal laboratory staff delivered a number of lectures at the Annual Meeting of the Western Canada Fuel Association (Edmonton, May 25-26, 1955), and two papers dealing with combustion of coal and with the properties and utilization of immature coals were presented at the Annual Western Meeting of the C.I.M.M. Some of these talks have already appeared in print and the others are scheduled for publication in the near future. Three members of the coal research staff co-operated in producing various sections of a report on "Energy Resources of Alberta". This report forms part of the Alberta Government's submission to the Gordon Royal Commission on Canada's Economic Prospects.

PETROLEUM

The work of the petroleum section has its roots in Athabasca oil-sand studies but it has spread to consideration of western oils in general. Recurring mention of the oil sands in the following discussion of the specific topics in hand indicates this path of development.

An engineering and economic study of the practicability of oil-sand development that was carried through during 1950 revealed that the oil-sands oil had a comparatively high content of trace metals. Since these metals are a source of trouble in refining operations, determination of their mode of occurrence in the oil-sands oil was indicated. During the resulting investigation it was natural that the trace metal contents of other crude oils from reservoirs of the same geological age—Cretaceous—should be examined. It was observed that the ratio of nickel to vanadium in these oils was nearly constant. It was then found that there were values for this ratio that were characteristic of oils of other geological ages. It thus appeared that the nickel-vanadium

ratio provided a means for determining the geological age of an oil. This age might or might not be the same as the age of the reservoir from which the oil came. So, determinations of nickel-vanadium ratios for the oils in the various oil fields provide further data upon which to form judgment on the practical problems of oil migration and accumulation.

Although the ratio of nickel to vanadium in various crude oils of the same geological age is constant, the actual quantities of these metals in the various oils is not constant. The variation is pronounced in an age group such as our Cretaceous oils that embrace oils ranging from heavy to light gravity. The heavier gravity oils of the group have the higher trace metal contents. The reason for the variation would seem to be related to the natural processes by which crude oils become "heavy" or "light". In the formation of oil from the original source material, does the oil commence by being heavy and then become gradually lighter because of the effect of such factors as time, temperature and pressure? Or do changes take place in the reverse direction? Trace metal contents of crude oils offer a way of probing into this fundamental question.

That crude oil has been formed in nature from animal and plant remains of bygone geological time is now the accepted belief. Both animal and plant matter contain a type of fairly complex organic compounds called porphyrins. A metal is built into the structure of a porphyrin. Two common examples are chlorophyl which contains magnesium, and haemoglobin which contains iron. Porphyrins are present in crude oil and contain nickel or vanadium or other trace metals. Thus, the porphyrins in crude oils look like a link that connects them closely with the animal and plant material from which they originated. It is a fair assumption that conditions which will change porphyrin contents from those present in animal and plant matter to those observed in crude oils, are similar to conditions that have converted this source material to the crude oils in our oil fields.

It can be seen that the trace metal and porphyrin contents of crude oils provide a promising avenue of approach to insight into the practical and fundamental problems of the migration and accumulation of our western oils, and to the general problem of the origin and generation of crude oil. The progress in making use of this approach during the past year is indicated in topical discussions that follow.

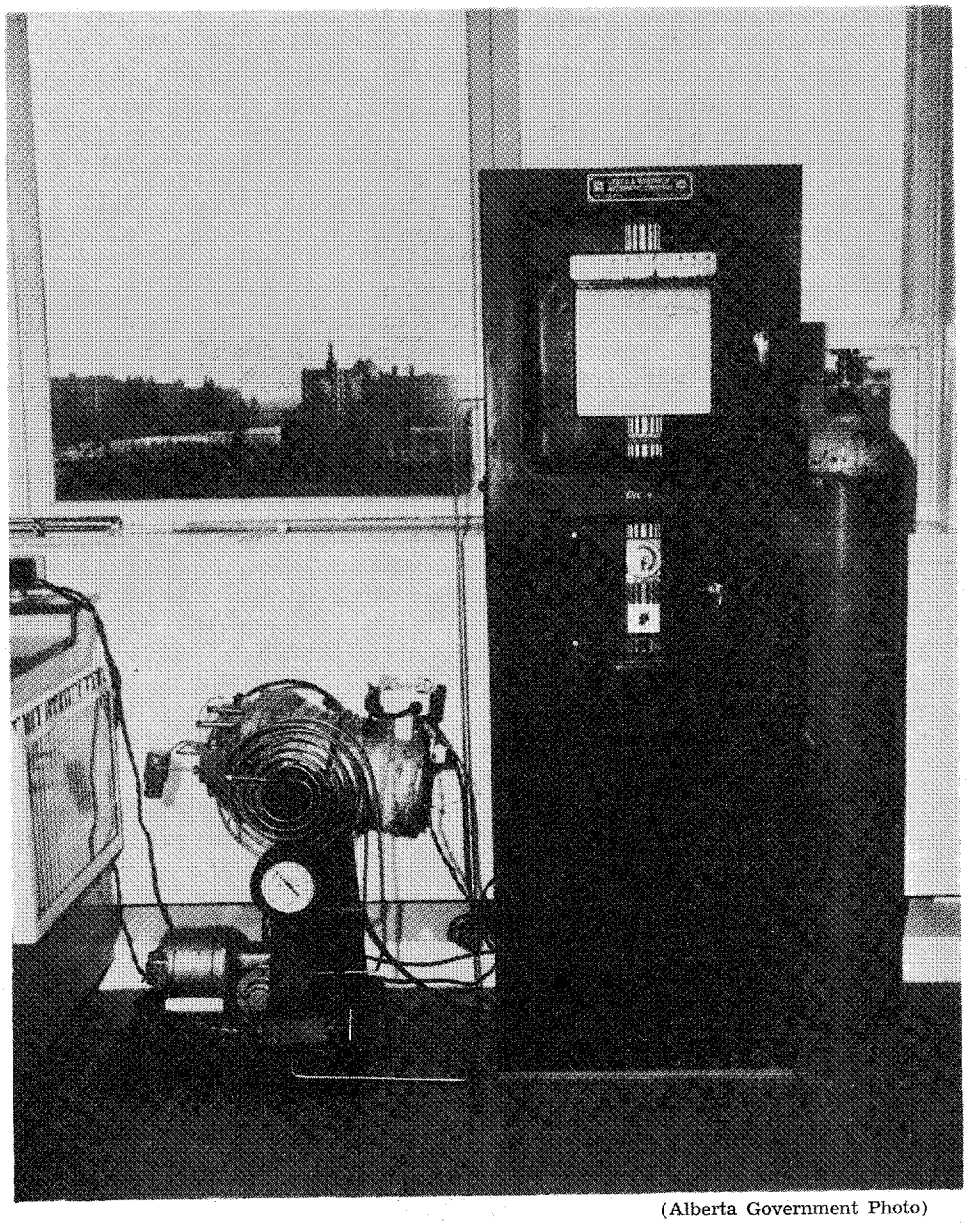
The heavy crude oils of Alberta are, at present, overshadowed in importance by the light gravity oils pouring from our oil fields. Although the heavy oils in the province which are produced by conventional means in the Bonnyville, Vermilion, Wainwright, Kitscoty, Lloydminster group account for only about 5 per cent of the province's reserves, the market for these oils is steadily increasing. When the enormous reserve of black oil in the McMurray oil sands—estimated to be in the hundreds of billions of barrels—is taken into consideration, it becomes apparent that heavy oils are an appropriate topic of study. The function of research is to make use of the present in gaining knowledge that will be wanted in the future.

Most heavy oils have a high sulfur content, and it ranges from about 3 per cent in the Lloydminster group of oils to about 5 per cent in the McMurray oil. It is an unwanted constituent. Coping with the sulfur problem would be facilitated if more were known about the sulfur-bearing compounds in heavy oil. Fairly satisfactory methods for determining the types and quantities of sulfur compounds in gasoline are available. But these

methods are of little use in studying heavier petroleum products and crude oil. A generally applicable analytical method by which classes of sulfur compounds can be identified and quantitatively measured is much needed. Progress that has been made on the study of heavy oils and the sulfur problem is reported in the following text.

Maturation of Petroleum

The examination of the occurrence of trace metals in crude oils has shown that the metals may be used in the correlation of one crude oil with another. This system has been found to be very useful in the regional picture



(Alberta Government Photo)

High pressure reactor used in petroleum geochemical research.

but in general it is subject to the overriding alterations of crude oils caused by the particular oil-maturation factors of a given region.

The factors involved in the maturation of organic material to petroleum are reasonably well-known, but the relative importance which must be assigned to each of the various factors is not well-known. Obviously, the three most important factors are temperature, bacterial action, and catalysis. The role of bacterial action has not been studied here, but fairly extensive investigations at other laboratories have shown that the bacterial action is quite important in the first stage of oil formation. It is probably responsible for the loss of the major part of the organic debris in the sea and for the removal of oxygen from the organic debris that ultimately is transformed to oil.

The second factor—temperature—has been the subject of investigation here, insofar as it affects the trace metal content of a maturing crude oil. An oil which is high in trace metals, low gravity, and is apparently a young crude oil—the McMurray oil—has been subjected to thermal degradation or maturation. In a high-pressure reactor the oil has been "matured" at temperatures of 350°C. to 420°C. for one to 300 hours. The kinetics of the maturation has been examined, and reaction rates for the removal of vanadium and nickel have been found to be of first order. At 350°C. the rates are about 0.01/hr. Activation energies for these two reactions are about 56 Kcal./mole.

Similar data for magnesium and the porphyrins have been obtained. The reaction rates for both appear to be appreciably higher than for vanadium and nickel.

The thermal maturation data are for the most part what would be expected from the observed values for the crude oils of Western Canada. The vanadium to nickel ratio observed for the crude oils fell with increasing maturation, and the same qualitative change has been observed for the thermally matured oil.

Quantitative examination of the several reactions shows that geological time has been too short to account for the observed maturation of crude oils in Alberta at the temperatures usually regarded as reasonable during geological time. If we accept the fact that bacterial action is very short-lived in the genesis of oil, it seems obvious that considerable stress must be laid to the importance of catalysis in the formation of crude oil as we find it.

Carcinogenicity of Petroleum

A survey of the carcinogenicity of crude oils of Western Canada has been undertaken. Two methods of assessing the cancer potency of the oils have been used, but the results do not indicate outstanding success. The data are badly scattered and the two methods do not agree at all well. However, there is some reason to believe that the heavier oils are characterized by lower cancer potencies than are the lighter oils.

Storage and Handling of Heavy Crude Oils

The settling rates of particles in emulsions of water in crude and refined oils were studied by measuring the rates of fall of five sizes of radioactive steel balls ranging from $\frac{1}{16}$ to $\frac{1}{4}$ inch in diameter in an apparatus which incorporated the basic design of a falling-ball viscometer. Two refined oils, two kerosine-diluted McMurray oil-sand oils, the McMurray oil itself and the water emulsions of these oils were studied. The water concentration

ranged from 0 to 35 per cent by volume at temperatures from 70°F. to 180°F. Stokes' Law corrected for wall effects was used in comparing the predicted with the determined rates of fall. An increase in the water concentration of any emulsion reduced the rate of fall. The emulsions were found to be Newtonian in character in the temperature range studied. The viscosity of an emulsion as determined by conventional means was found to apply in the Stokes' equation for determining the terminal velocity of a particle under conditions of laminar flow. The viscosity of an emulsion of the McMurray oil in terms of the viscosity of the dry oil and the water concentration was found to be

$$n = n_o (1 + C + 14 C^2 + 26 C^3).$$

Thus it is possible to calculate the settling rate of a solid particle in an emulsion of McMurray oil, given the viscosity of the dry oil and the concentration of water in the emulsion.

Study of the "Heavy Oils" of Alberta

In the preceding Annual Report it was mentioned that a lead had been obtained regarding the preparation of a binder, for briquetting coal and for use in preparing metallurgical coke, which appeared to have very desirable properties. The work this year has been focused on possible source materials, methods of manufacture, and evaluation of the briquetting binder. Although progress has been made, the investigation is still in a state of flux and it is too early to attempt to outline the results.

Sulfur in "Heavy Oils"

The sulfur study this year was devoted entirely to the flash distillation product from McMurray oil-sands oil, the distillate containing 4.37 per cent of sulfur. This distillate had been divided into three fractions by vacuum distillation to facilitate the study.

Previous work had shown that the resolution of the sulfur-containing compounds in each fraction according to their sulfur bondings by following the procedure outlined by the U.S. Bureau of Mines in Report of Investigations No. 3591, with modifications, was not satisfactory as there always remained a substantial proportion of residual sulfur whose resolution into its constituent groupings was not successful. This was due to the apparent decreased sensitivity to extraction procedures of the sulfur groups when present in large molecules in the higher-boiling components of the fractions.

By employing chromatography on the distillate fraction—using silica gel, alumina, and silica-alumina as adsorbents—high sulfur concentrates were obtained for further study. Both elution and displacement techniques were applied successfully. For example, from fraction I on silica gel, a portion was eluted which represented 13 per cent of the fraction but contained 54 per cent of the sulfur; also, from fraction I on silica gel impregnated with mercuric acetate, elution produced an apparent division of the sulfur compounds as follows: aromatic sulfides 5 per cent, alkyl sulfides 52 per cent, and thiophenes 42 per cent.

The above studies indicated that extraction methods for the removal of sulfur from the oil-sands oil would not be feasible. The high sulfur content of the oil, together with the high molecular weights of the sulfur compounds, would result in too great a loss of the oil if removal of the sulfur were based on extraction of the sulfur compounds by physical or chemical means.

Possible methods of desulfurization thus were reduced to:

(1) Catalytic hydrogenation at high temperatures and pressures using a minimum of hydrogen, to remove the sulfur as hydrogen sulfide;
(2) Catalytic decomposition at high temperatures, both at atmospheric and elevated pressures, to remove the sulfur as hydrogen sulfide;
(3) Oxidation to decompose thiophenic compounds.

The scientific literature contains a large amount of information on catalytic hydrogenation. It is an expensive procedure when considerable sulfur is present and when trace metals which will reduce catalyst efficiency are also present. Consequently desulfurization studies are being devoted to catalytic decomposition and to oxidation.

In catalytic decomposition, alumina is a common catalyst for the removal of sulfur from aliphatic and naphthenic sulfides, whereas for oils containing large amounts of aromatic and/or thiophenic sulfur, special catalysts are required —usually an alumina carrier with oxides of metals such as molybdenum, cobalt, vanadium, magnesium or iron as promoters. Sulfur removal by this means results in the formation of cyclic, aromatic, and olefinic compounds.

The practicability of oxidation to decompose thiophenes depends on the stability of the balance of the oil to the oxidation conditions that have to be used, and on the value of the products. The method involves the release of the sulfur in the thiophenes as sulfur trioxide, and quite rigorous conditions are necessary. A preliminary partial catalytic hydrogenation or catalytic decomposition to remove sulfur from the non-thiophenic sulfides would be required to avoid their oxidation to stable sulfones.

The catalytic decomposition and oxidation studies are still in their early stages. Continued work on these phases should develop points both of fundamental interest and of practical importance. These degradative procedures will permit more accurate determination of the constituent groups present in sulfur-containing compounds, and the results should be unaffected by the presence of sulfur compounds of high molecular weight which did not respond to previous methods involving physical or chemical measurements.

During the year many samples of pure sulfur compounds as reference compounds, and portions of the oil fractions separated from chromatographic columns, were examined by infrared spectrophotometry. The results, on the whole, were not definite enough to warrant the adoption of the method as a regular tool of analysis at this stage of the investigation.

NATURAL GAS

The research program on natural gas and its chemical utilization has been directed to three separate projects, and a final report has been written on a fourth. Part of the objective of the research program has been the maintenance of a center of knowledge concerning developments in the petrochemical field and their significance to Alberta. A useful by-product of this part of the program was the preparation of a report on "The Petrochemical Industry" as part of the Alberta Government's submission to the Gordon Royal Commission on Canada's Economic Prospects.

Partial Oxidation of n-Butane Project

Work was continued on the partial oxidation of n-butane and a paper on earlier work was presented before the Annual Conference of the Chemical Institute of Canada in Quebec City, in June 1955. A much clearer picture

of the nature of the partial oxidation reaction is beginning to emerge. There seems little doubt that the reaction is essentially that of a "cold flame", characterized by a pronounced induction period, a very sharp reaction peak and self-quenching termination. "Cold flames" occupy an intermediate position between slow oxidation and flame combustion.

Recently, the effect of an inert diluent, nitrogen, on the reaction of an equal molal mixture of oxygen and n-butane has been investigated. The partial pressure of nitrogen was varied between 18 and 230 p.s.i.a., while the partial pressures of oxygen and butane were each held constant at 5 p.s.i.a. and showed signs of tapering off at the high nitrogen pressures. The induction period has been shown to be strongly dependent upon the surface-to-volume ratio in the main reactor, as well as upon the nature and severity of the butane preheating treatment.

The over-all characteristics of the reaction have been fairly well defined and this phase of the work is about over. The next logical step would be to carry out detailed mechanistic studies but this would probably involve a different approach and different experimental techniques.

Carbon Black Project

This work was undertaken in order to make an engineering evaluation of the permeable tube process for producing carbon black from natural gas, and a report on the work to date is being published as Mimeographed Circular No. 20. The main conclusions are:

(1) The use of the permeable tube technique has enabled the production of carbon black from natural gas to be carried out continuously for periods up to four hours. Without this technique operation at comparable conditions was possible only for about fifteen minutes. It is entirely possible that continuous operation might be practical with a "make" period of say three hours, following by a "burn" period of perhaps fifteen minutes during which any carbon deposited on the tube walls is removed by an oxidizing gas or by steam. The "plugging" problem has been reduced to controllable proportions. Certain modifications in operating technique, such as the substitution of steam for flue gas as the diffusion stream, might solve this problem entirely.

(2) Carbon black yields and quality are comparable to those commonly found for furnace gas processes. The black is of medium quality and satisfactory for compounding certain types of synthetic rubber.

(3) Thermodynamic analysis indicates that the process should be self-sufficient thermally, i.e. the off-gases have enough heating value to operate the carbon black furnaces without requiring supplemental fuel.

(4) Tubes of two-inch inside diameter appear to be about the optimum size. Smaller tubes have too high a surface-to-volume ratio, and hence require too high a flue gas diffusion rate. Larger diameter tubes would impose an excessive heat transfer load on the tube, causing unduly high thermal stresses in the tube wall.

(5) The durability of the alundum tubes may be a serious problem in commercial installations. Frequent tube breakages were encountered in the experimental tests. Whether this fragility is inherent in the tubes or is merely a result of the specialized nature of the test equipment and procedure is not known. The tube manufacturers, upon

personal contact, insist that installations of this type should last for months of continuous operation.

But, while the technical problems likely to be encountered in an industrial adaptation of the permeable tube process for producing carbon black from natural gas are probably not insuperable, no economic evaluation would be valid without further comprehensive and extended tests on a semi-works scale. In any judgment on whether or not such efforts are likely to be worth-while, the background of rapid technological change in the carbon black industry must be considered. The past five years have seen a very rapid development of alternative carbon black processes using petroleum fractions as raw materials, and now almost half of the total carbon black production comes from this source. In the face of this unmistakable shift to oil blacks, it is doubtful whether any normal modifications of existing gas black processes can reverse this trend.

High Temperature Pyrolysis of Butane Project

Since this is a new investigation, some preliminary discussion is in order. No systematic correlations and very little data of any kind are available for the high temperature pyrolysis of butane. However, it is known that the lower paraffin hydrocarbons at high temperatures and low reaction times will pyrolyze to give substantial yields of acetylene. Considerable industrial interest has arisen in the production of acetylene from natural gas and, although many process difficulties are yet to be resolved, it seems likely that petroleum hydrocarbons will eventually replace calcium carbide as the primary source of acetylene. Butane was chosen as the paraffin to be studied in this investigation, both because of its high reactivity and because it will be available in large quantities and at fairly low prices in the near future as large scale export of natural gas from Alberta proceeds.

In the decomposition of butane in an externally heated ceramic tube one encounters the same practical difficulties as in carbon black production, namely, tube stoppage or "plugging" due to carbon deposition on the inside tube wall. However, by keeping the partial pressure of butane low (accomplished by dilution with nitrogen), and space velocities high (of the order of 30 reciprocal seconds), it has been possible to carry out a series of tests which, although of short duration, do reveal much of the nature and character of the pyrolysis reaction. Tube temperatures were held at about 2500°F. Several space velocities have been investigated and the results show that:

(1) Lower partial pressures of butane favor the formation of acetylene; higher pressures favor ethylene.
(2) Acetylene yields upwards of 20 per cent of the original hydrocarbon charge (by weight) have been obtained. These are in the region of commercial interest.
(3) The problem here is essentially one of heat transfer rather than one of kinetics.

Even the preliminary work to date has suggested a number of research problems that may be investigated, including the development and testing of new reactor systems.

Natural Gas Systems

Work is under way on the separation of undesired components from natural gas.

HYDROCARBON RESEARCH

(PHOTOCHEMISTRY)

The research program of this section has been devoted to studies of vapor phase chromatography, a new method for the rapid analysis of gas mixtures utilizing the principles of the more familiar liquid chromatography. Considerable experience has been gained in the treatment of various kinds of gas samples, especially along the lines of interest to this and other sections in the Council.

Apparatus has been designed and is in the process of construction for fundamental studies on the kinetics of the pyrolysis of compounds of interest to the natural gas and petroleum sections. Present emphasis in this field is placed on an attempt to separate the free radical from the molecular decompositions of simple hydrocarbons.

It is hoped that the vapor phase chromatography technique will be of great value in this research as well as in some geophysical research which may be initiated in the coming year.

GEOLOGY

Introduction

During the past year, four projects—oil-sand area, clay research, glacial studies, and micropaleontological research—were carried over from 1954. In addition, three new projects were undertaken—a groundwater survey of the province, stratigraphic studies of the southern foothills, and a laboratory study on the chemical variation between marine and non-marine sediments.

Council's list of geological literature has been increased by some eight publications in the form of reports, preliminary reports and contributions.

Oil-sand Area

The geology along the Firebag and Clearwater rivers was surveyed from the eastern boundary of Alberta to the Athabasca river. On both of these rivers the eastern limit of the oil impregnation of the McMurray formation has been determined. Heavy oil was found in fractured Devonian limestones in township 97, range 7, west of the Fourth Meridian. Stratigraphically above the fractured Devonian formation, the McMurray formation is saturated with oil. Above the McMurray formation, a black shale section was measured, and the microfauna is being studied so that an age determination can be made.

The geological sections on the Upper Clearwater river and the High Hills river include an upper sand formation above the McMurray formation, separated from the McMurray formation by the Clearwater marine shale. Tentative correlation is made between this upper sand and the Grand Rapids formation of the Athabasca section.

Subsurface information received from operating companies in the oil-sand area has been recorded. Correlations between the test holes have been made on the base of the McMurray formation and the base of the Clearwater shale.

Clay mineral studies on the fine-grained portion of the McMurray formation indicate that kaolinite-to-illite ratios support the contention that the McMurray is a continental deposit.

Air photograph interpretation on the region between McMurray and Lake Athabasca shows that the muskeg areas are discontinuous and are divided

by long sand ridges of glacial origin. Extensive gravel deposits in the form of large conical domes (kames) occur along the Firebag river.

Areal mapping of the McMurray formation has now been completed, and a map and report will be published, which will be Part III of "Geology of the McMurray Formation".

Clay Mineralogy

During the 1955 field season three incomplete sections of Bearpaw were studied and sampled in south-central Alberta. Lithologic logs of these sections were prepared, and analysis of samples collected will be made during the coming year. In addition, field studies of the Blairmore formation were undertaken in the Blairmore area. Sandstone samples were taken for future sedimentation studies, and samples of typical Blairmore shales were taken for clay mineralogy studies.

Preliminary X-ray diffraction studies have been completed on 175 of the samples collected during the 1954 field season. These studies show that the dominant minerals in the clay fraction of the Bearpaw shale are montmorillonite, illite and a chlorite or kaolin mineral, which will require more detailed study for definite identification. The dominant clay mineral in most and probably all the samples is montmorillonite which is a mineral normally expected to predominate in non-marine shale. Fossil evidence shows the Bearpaw to be marine. Further studies may help to clear up this apparent anomaly. The sand and silt fractions of the shale consist largely of quartz and feldspar. Detailed quantitative analyses of Bearpaw samples are currently being undertaken.

In conjunction with Imperial Oil Limited a joint research project on carbonate rock has been initiated. The purpose of this investigation is to evaluate X-ray diffraction as a tool for the determination of calcite-to-dolomite ratios and to determine whether any other measurable property of carbonate rocks may prove to be of value in their study.

Glacial Geology

The glacial geology program, which was started in 1954, was continued on a slightly expanded scale in 1955. Two parties were fielded—one in the Alliance-Brownfield district and the other in the Castor district. The mapping of these two districts was completed and a preliminary report will appear in the coming year.

Experience gained over the past two field seasons indicates that air photographs can be of great use in mapping subsurface features such as buried valleys, buried escarpments, thin till coverings over bedrock, etc. Groups interested in oil production and construction work of various types have expressed interest in having a series of "type" photographs of Alberta glacial features published. Work is now in progress to compile such a group of photographs.

With the exception of the northern part of the Castor area, sufficient reserves of sand and gravel have been outlined to take care of any future development of this region. Most of these gravels are associated with postglacial drainage patterns.

An extensive drilling program supplemented the mapping, and the thickness of glacial material has been outlined for much of the area. It was found that, for the most part, the glacial materials are quite thin, generally

under 25 feet, and overlie the Edmonton and Bearpaw formations. As a result, most of the groundwater in this area is taken from bedrock. One important exception to this general rule can be found in the Brownfield district where several buried valleys contain appreciable amounts of fresh water. These valleys can and have been mapped directly from the air photographs.

A laboratory research program on the base-exchange characteristics of colloidal-size quartz has been completed. Quartz was ground to colloidal size and then treated with various cations to determine base-exchange characteristics. It was found that quartz has a very low base exchange which might be important in interpreting the base-exchange characteristics of soils which have a high quartz content in the clay size.

Groundwater Geology

Primary attention throughout the summer period has been given to an assay of Alberta's groundwater potential, matched against present and future demand from rural settlement, municipalities and industries.

The geology and climate of Alberta create an environment for groundwater which ranges from very poor to excellent. With the exception of parts of the Peace River country and certain localities, generally north of township 9, east of Bassano, Hanna, Tofield and Fort Saskatchewan, and eastward to the Fourth Meridian, conditions are favorable for obtaining 3-10 gallons per minute from small drilled wells for farm supply. This favorable condition arises from the widespread occurrence of Tertiary and Cretaceous sandstones which are sufficiently permeable and water-bearing to permit satisfactory low-cost well construction. It is not likely that these formations will be overpumped by rural users under present climatic conditions and agricultural development.

Groundwater resource problems of a serious nature are arising and will continue to arise with increasing severity with industrial and municipal need for high-capacity water wells. It appears that less than 10 per cent of the total land area east of the Rockies and south of township 85 has natural conditions which favor the construction of wells yielding in excess of 100 gallons per minute. This means that up to 10 per cent of this territory has, regardless of available surface water, an industrial-municipal water potential that is clearly superior to the remaining 90 per cent. It is vital to the growing economic strength of Alberta that the unusually favorable groundwater areas be determined, mapped and publicized.

The second major role of the geologist in groundwater work is concerned with the means by which water is withdrawn from the earth. Therefore, a wide variety of well construction techniques practiced in Alberta have been scrutinized, comparing the level of water-well engineering with that in other regions in North America.

Among the 117 registered water well contractors in Alberta only four or five actually have experience in the construction of high-capacity wells. The remaining bulk of drillers handle the farm and domestic needs. Quality of industrial-municipal well construction is fair to good, although much improvement can be achieved in such matters as selection of artificial gravel pack material, selection of commercial well screens, the execution of proper test drilling programs prior to permanent well construction, and in special techniques by which the yield of wells can be greatly increased. Well con-

struction on farms is of a low order, with some notable exceptions in the case of unusually competent drillers where customers are willing to pay for good construction. It is certain that per capita use of water on the farm will increase markedly in the next ten years, by garden irrigation, laundry appliances, and more plumbing. The demand for better rural well construction arising from increased water use will probably lead towards greater willingness to pay for water in terms of what water is worth. Slow but marked improvement in rural well construction is anticipated.

An effective groundwater research program requires the availability of technical information. A fair volume of logs of water wells, reports on well construction, interpretations of electric logs and municipal groundwater information has been collected from a multitude of sources and filed systematically. These should be a permanent and ever-growing part of the technical records of the Research Council. The co-operation of the Department of Water Resources and Irrigation, and the Petroleum and Natural Gas Conservation Board has been most helpful to the developing groundwater program. Both these organizations have much information and data bearing on the groundwater research program.

A small number of first-class groundwater research groups in the United States effectively use the electrical earth resistivity technique for assaying groundwater possibilities, particularly in glacial drift and in valley alluvium. The method may also be used in plotting ancient stream courses, where these old channels are filled with sand and gravel and buried by glacial debris. Through the courtesy of the Illinois Geological Survey sufficient resistivity equipment was brought to Alberta to test the applicability of the technique in this province. Sufficient time was devoted to earth resistivity work to fulfill the purpose of this phase of the summer's work.

Both the glacial drift and the alluvium of stream valleys in Alberta appear to have suitable mineral and water make-up to permit satisfactory use of the electrical earth resistivity method of prospecting and investigation. This study indicates that non-water-yielding glacial till in central Alberta has a resistivity of approximately 1000-3500 ohms per cubic centimeter. Water-yielding sand and gravel bodies in glacial drift and also stream alluvium have apparent resistivities of 3000-25,000 ohms. Therefore geophysical detection of buried sands and gravel for the identification of potentially water-yielding areas is promising. Successful research of this type requires careful use of data and thorough integration with reliable geological information.

Micropaleontological Research

The summer's work was begun by editing in final form with Dr. C. R. Stelck of the University of Alberta, Research Council of Alberta Report No. 70, "Foraminifera of the Cenominian *Dunveganoceras* zone from Peace River area of Western Canada". This report based on the authors' theses had been compiled during the preceding year as a sequel to Report No. 68, "Kaskapau Foraminifera from Peace River area of Western Canada" by C. R. Stelck and J. H. Wall. Both of these reports deal with the establishment of microfaunal zones in the Cenomanian and Turonian stages of the Upper Cretaceous, the calibration of these zones with megafaunal sequences and their subsequent correlation with sections in distant areas, the formal description of the commonly-occurring species of Foraminifera, and ecological considerations.

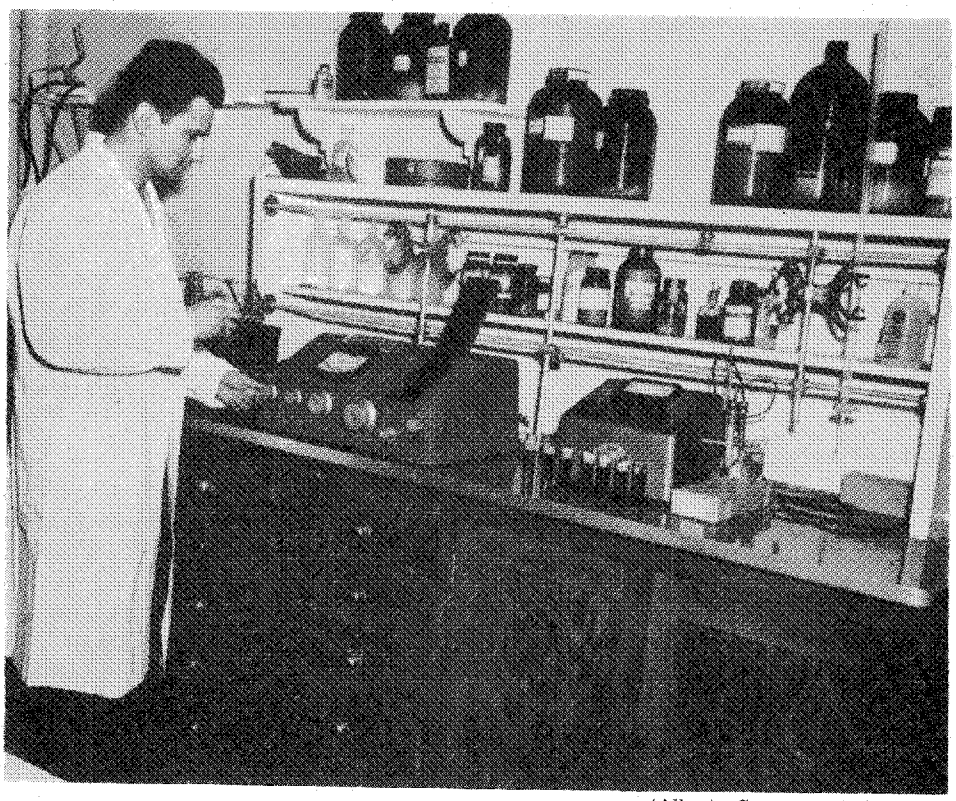
A large part of the summer was devoted to the preparation for publication of the paleontological portion of an M.Sc. thesis by Mr. G. B. Mellon. The ensuing report (No. 72), is entitled, "Geology of the McMurray Formation—Part I, Foraminifera of the Upper McMurray and Basal Clearwater Formations" by G. B. Mellon and J. H. Wall. In this contribution, a number of foraminiferal species from the two formations are described and the microfaunal assemblages correlated with other Albian (late Lower Cretaceous) suites in Alberta. An effort is made also to reconstruct the depositional environment from evidence supplied by the microfaunal units.

Currently, a report is being prepared under Dr. C. R. Stelck on Middle Albian Foraminifera, based on University of Alberta theses by C. R. Stelck, L. J. Martin, and W. G. Bahan.

Special Projects

A. Silicate Analysis.

Recent work on the Gulf Coast and on the coast of California indicates marked differences in chemical and mineralogic constitution between marine and non-marine shales. This research has been conducted largely on Recent and Pleistocene materials. In order to check the applicability of the results of this research to older sediments, a section across the Oldman-Bearpaw contact on the St. Mary river was sampled. At present, the clays are being separated from these samples, and chemical and mineralogical analyses are being carried out. Chemical analyses follow the U.S.G.S. specifications for silicate analysis.



(Alberta Government Photo)

Silicate analysis of clay fractions from marine and non-marine shale.

B. Peace River Iron Ore.

Samples from cores of the oolitic iron deposit in the Peace River area have been taken at intervals and these samples are now being checked for insoluble content and thin-section analysis. In addition, microfossils are being separated from the shale fractions of the cores for dating purposes.

SOILS

Soil Surveys

The Council's soil surveyors were again engaged principally in the Peace River district of Alberta. However, the exploratory soil survey by helicopter extended into other districts.

Field work in connection with the reconnaissance soil survey of the Beaverlodge sheet was completed in 1955. About 20 townships were completed and a considerable portion of the sheet was checked. It is expected that the final checking will be done during the next field season. The area consists of townships 67 to 75 in ranges 8 to 13, inclusive, west of the Sixth Meridian. Final checking of the Grande Prairie-Sturgeon Lake area was completed in 1955. The area consists of townships 67 to 75 in ranges 20 to 26, west of the Fifth Meridian and ranges 1 to 6, west of the Sixth Meridian.

The first attempt at making an exploratory soil survey by helicopter was completed in September, and it seems evident that this venture was quite successful. Three areas (map-sheets J, F, and L) were traversed and inspected, and thus exploratory soil information was gathered on some 16,500 square miles or roughly 10½ million acres. Each sheet was surveyed by helicopter from a central base; for Sheet L the central base was on Cutbank river about 70 miles south of Grande Prairie, for Sheet F the helicopter was based at Obed, west of Edson, and for Sheet J the base was Ft. Assiniboine, northwest of Westlock.

In order to carry out such a survey efficiently and successfully, all pertinent aerial photograph information must be transferred to base maps before the helicopter survey is made, and thus a great deal of preparatory mapping is required. In this connection it should be stated that the preparatory mapping done in 1954-55 by the Forestry Division of the Department of Lands and Forests was very much appreciated, and the Advisory Committee*, at its meeting on October 27th, passed a resolution expressing its appreciation to the Department of Lands and Forests for its financial support of the project in 1955-56.

Other Projects of Alberta Soil Survey

For purposes of interest, the following brief discussion of other projects of the Alberta Soil Survey, conducted mainly by Federal survey staff, is included in this report.

The reconnaissance soil survey field work on the Edmonton map-sheet was almost completed in 1955. The sheet covers about 2½ million acres and work on this area has been carried on for several years. It is expected that the reconnaissance soil survey of the Brazeau sheet will be completed in 1956.

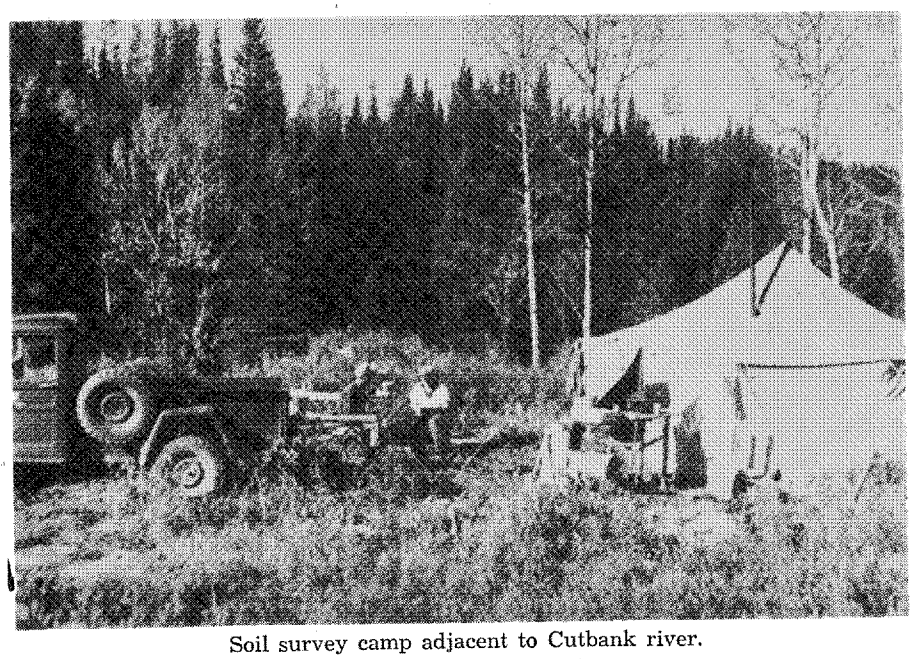
Detailed soil surveys were made of several small areas in 1955. In the Bow West irrigation area distributaries B and C and part of the Lomond dis-

*The Alberta Soil Survey Committee is Council's advisory committee on soils and is responsible for planning the joint program conducted by the soil survey staff of the Canada Experimental Farms Service and the Research Council of Alberta through the chairmanship of the Professor of Soil Science of the University of Alberta.

tributary were surveyed. In the St. Mary irrigation project a small area northwest of Bow Island was covered, and in the Patricia and Millicent districts salinity surveys were made and salty areas outlined. A detailed soil survey was made of the new Dominion Government substation on solonetzic soil at Vegreville.

During the year considerable assistance was given to the assessors of the Department of Municipal Affairs.

Helicopter at landing strip beside the soil survey camp on Cutback river, south of Grande Prairie.



Soil survey camp adjacent to Cutbank river.

Other Activities

The senior provincial and federal soil surveyors, several other soil surveyors, and the chairman of the Alberta Soil Survey Committee attended the Agricultural Institute of Canada convention (including meetings of the affiliated Canadian Soil Science Society) in Edmonton, June 20th to 24th. The senior surveyors and the chairman also attended the meetings of the National Soil Survey Committee in Saskatoon, October 31st to November 5th. Various soil survey inspection and correlation trips were made during the field season by the chairman and senior soil surveyors.

Irrigation Research on Solonetzic Soils*

The work done in 1955 at Youngstown was a continuation of the irrigation plot experiments started in 1952 and 1953. The "A" plots were started in 1952 to study mainly the effect of soil amendments on the physical structure and productivity of solodized solonetz soils under irrigation. The treatments were sulfur, krilium, gypsum, manure, deep cultivation, and two checks— one irrigated and one dry. The treatment of the plots was replicated four times. These plots are irrigated by the surface-rill method. In the fall of 1953 the "B" plots were started and were designed to study the effects of cultural and legume treatments on the physical structure and productivity of solodized solonetz soils under irrigation and dry conditions. The main treatments used on these plots were: deep plowing (18″), deep cultivation (20″), shallow deep cultivation (farm tractor power with subsoiler), alfalfa, and check. The plots were designed so that they could be irrigated with a sprinkler system.

Field Results—"A" Plots

Sweet Clover—average yields

	1954 T./acre	1955 T./acre
Deep cultivation	2.2	0.91
Krilium	1.9	1.10
Gypsum	1.9	0.90
Sulfur	1.8	0.61
Manure	1.7	0.89
Irrigated Check	1.8	0.89
Dry Check	0.9	0.35

Wheat—average yields

	1953 bu./ac.	1954 bu./ac.	1955 bu./ac.
Manure	28.8	25.4	31.1
Krilium	22.8	20.3	29.1
Deep cultivation	23.6	18.8	27.9
Gypsum	29.3	18.3	26.8
Sulfur	28.1	15.7	30.6
Irrigated Check	19.3	16.1	24.5
Dry Check	12.7	9.9	12.9

*The irrigation research project on Hemaruka solonetzic (hardpan) soils at Youngstown is a co-operative investigation involving the University of Alberta Department of Soil Science, the Research Council, the Canada Experimental Farms Service, and the Provincial Department of Agriculture.

Field Results—"B" Plots

	Wheat—average yields				Oats—average yields	
	Irrigated		Dry		Irrigated	Dry
	1954 bu./ac.	1955 bu./ac.	1954 bu./ac.	1955 bu./ac.	1954 bu./ac.	1955 bu./ac.
Deep plowing	22.1	31.7	16.5	15.6	62.6	33.4
Deep cultivation	22.3	30.5	12.3	17.8	53.8	27.9
Shallow deep	14.2	24.9	6.5	13.7	39.7	33.6
Shallow (normal)	12.2	24.3	4.9	11.8	34.0	31.6

Rainfall at Youngstown Plots (inches)—1955

May	June	July	August	September	Total 5 months
3.11	1.26	1.34	0.37	2.10	8.18

The summer months were relatively dry, and on the average the summers are dry in this area.

Penetrometer readings were taken on the plots in 1953, 1954 and 1955. The readings (isoprobes) indicate significant changes in soil structure due to cultural treatment.

Salinity data indicate extreme variability of salt content in the subsoil. A progressive increase in salt content with increase in depth is generally noted.

SUBSURFACE DRILLING

Subsurface investigation, commenced last year in studies on soils, geological formations, and irrigation problems, was continued. The operation employs a mobile drill mounted on a power wagon; usually the drill worked to depths of about 50 feet though greater depths were attained, as needed, under favorable conditions. During this second summer season, the drilling operation showed an increase of nearly 50 per cent in the work completed, and in the period May 15th to the end of August, 415 holes were drilled, with a total footage of 9,300 feet.

Many projects of Council were assisted in their investigations by the information supplied from drilling. Most of the time was allotted to the Pleistocene Geology survey in the Alliance-Brownfield-Castor area, and the Alberta Soil Survey on irrigation problems in the Youngstown area. Assistance was also given to Pleistocene survey work in the area between Edmonton and Fort Saskatchewan, the Canada Soils Survey in the Millicent and Lamont-Vegreville areas, and to the P.F.R.A.

The addition of coring equipment has been considered, but deferred for at least another year. The drill is fulfilling an existing need for subsurface information in its present form, and the considerable extra cost for coring equipment and additional crew is not yet warranted.

HIGHWAYS

The program of Highway Research is a continuing project which requires the carrying on of investigational work over a number of years before final conclusions may be drawn and full use made of the accumulated data. The program has the following present objectives:

(1) To determine the fundamental nature of the phenomenon by which migration of soil moisture to the frost line is prevented by lignosol;
(2) To determine whether other chemicals may be equally suitable in preventing frost heaving and development of frost boils;
(3) To treat one or more severe frost-heaving locations on Alberta's main highways.

Field trials in the winter of 1954 for the purpose of confirming on a field scale the laboratory tests as to the possibility of preventing frost heaving in soils by injection of lignosol and lignosol chromate mixtures, were made at locations on Alberta highways, two locations on the main line of the C.N.R., and on a section of Tarmac area at the R.C.A.F. station at Currie Barracks in Calgary. This field work was observed by a representative of the Highway Research Project, and checks were made on the effectiveness of the treatments. The results showed that the highly mechanized procedure developed was not as efficient as had been anticipated and also that the designed proportions of lignosol and chromate did not set up in the field into a gel as successfully as under laboratory conditions.

A laboratory program was therefore undertaken to investigate the reasons for this. This program was started in the summer of 1955. It has been found that the temperature of the chrome lignosol solution has a marked effect on its setting rate. The original strength and setting time design curves developed the previous year have therefore been extended to cover variations in temperature of solution. It was also found that if the chrome lignosol solution is frozen, it will not set up satisfactorily.

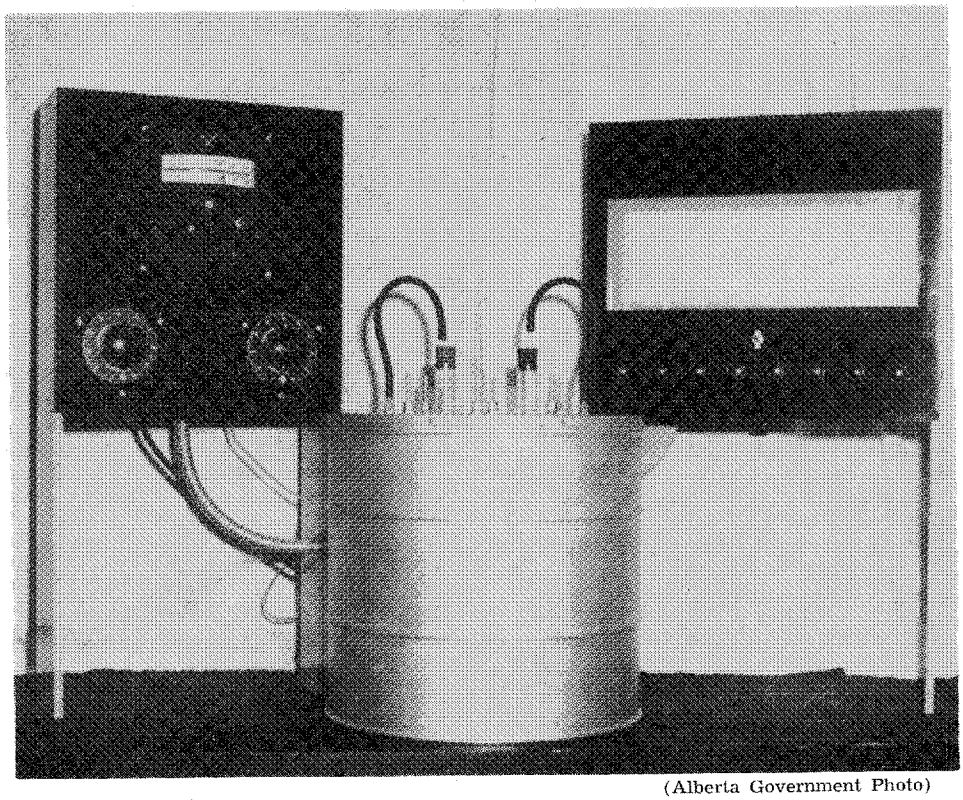
Further work has also been undertaken on the movement of chemical solutions through soils by the process of electroosmosis. It was found that the addition of lignosol would permit the solution to be moved by the process of electroosmosis through coarse sands for which the process was not effective in moving plain water. Additional basic data have also been secured on the electrical permeability of coarse sands and silts where both water and lignosol solutions were being moved. This work is of a fundamental nature, and it is hoped may have applications in the problem of the satisfactory injection of chemicals into fine-grain soils.

A series of major slides occurred on the new highway being constructed out of the Peace River valley at the town of Peace River during the fall of 1954 and the summer of 1955. The Department of Highways requested assistance from the supervisor of the Highway Research Project, in the stabilization of these slides. Investigations made in co-operation with the Department of Highways showed that the slides were the result of rather unusual soil and subsoil moisture conditions. It was considered that the problem required a certain amount of research work on the conditions. It was therefore decided to use the resources of the Highway Research Project in co-operation with the Department of Highways on the necessary studies; these are proceeding.

GASOLINE AND OIL TESTING

During 1955 the work of the Gasoline and Oil Testing section followed much the same pattern as during the previous year. The total amount of analytical work was approximately the same, although there was some change in the volume of samples received from certain sources. Test work carried

out for the Department of National Defence increased while that for the Provincial Government decreased slightly. It was not considered necessary to conduct the usual gasoline survey this year. While this reduced the amount of local work, it made time available to accommodate the larger number of samples received from the Department of National Defence. There was, however, considerable test work carried out for various other Government Departments, such as the Provincial Secretary, Attorney General, and the Provincial Highways.



(Alberta Government Photo)

Equipment used in the British Air Ministry test for determining the oxidation characteristics of aircraft engine oils.

While analytical testing represented the bulk of the work, other activities —some of a research nature—took up a considerable proportion of the time. The study of the deterioration of aviation gasoline during storage was continued during the year. This is a long-term project started three years previously for the Defence Research Board. Samples were removed at intervals from all drums of fuel in storage and a complete analysis was carried out on each sample. A report was prepared for the Canadian Army covering viscosity-dilution data determined on an SAE 5 grade of lubricating oil diluted with special arctic gasoline. In arctic locations it is often necessary to dilute even this light grade of oil in order to ensure the restarting of an engine after it has been shut down for any long period of time. No data were available to guide the vehicle drivers in determining the degree of dilution necessary for various weather conditions, and at the request of the Army these data were determined and compiled. Close liaison was maintained with the

Petroleum Specifications Committee of the Canadian Government Specifications Board, and considerable work was carried out on behalf of this group.

In preparation for the move to the Research Council laboratories, several major items of equipment received attention. These included equipment for determining the foaming characteristics of lubricating oils and equipment for the determination of viscosity; octane rating engines were altered to conform to the latest test requirements, and one engine was converted to run the research method of test; equipment for the British Air Ministry oxidation test for aircraft engine oils was designed and constructed.

INDUSTRIAL ENGINEERING SERVICES

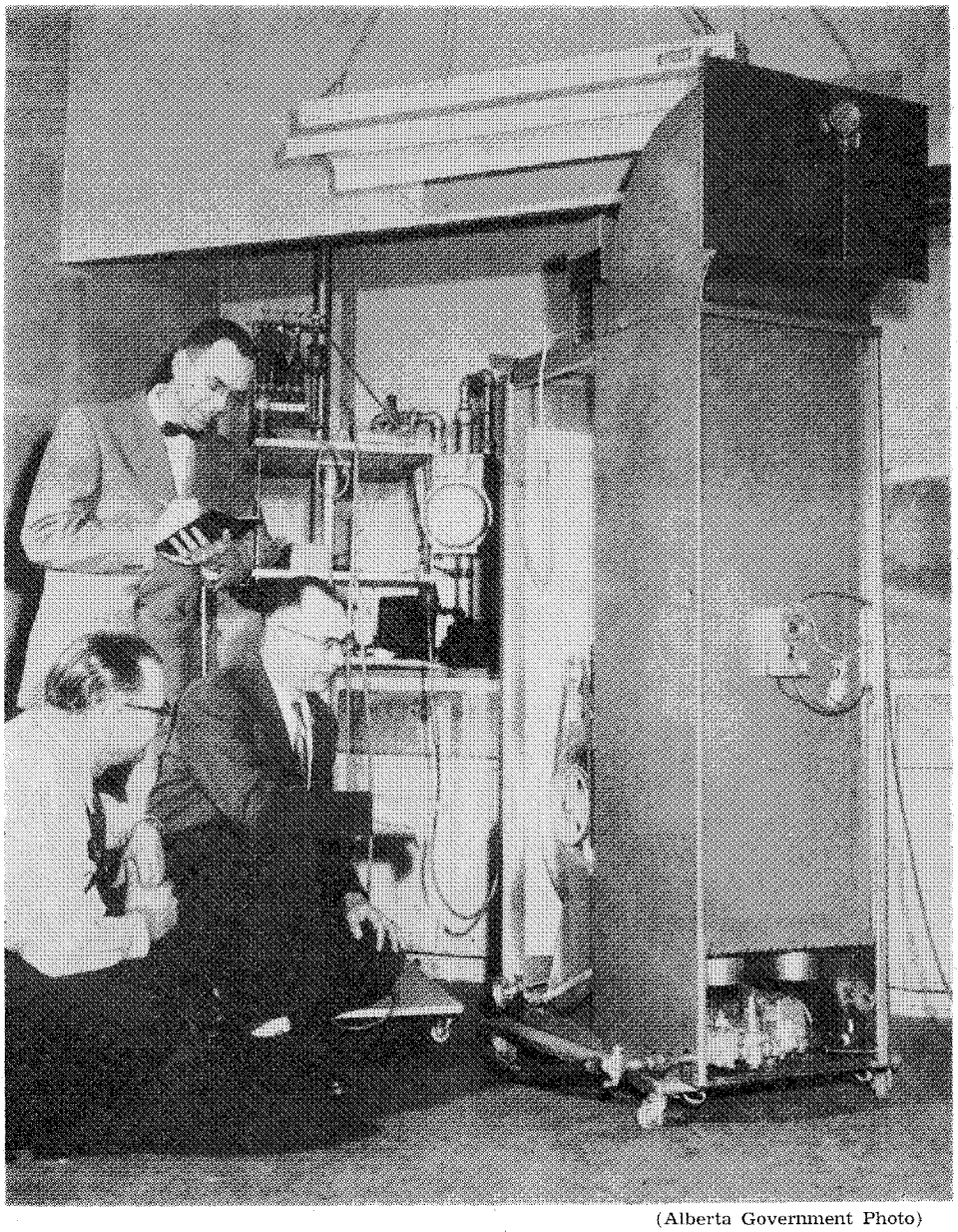
There are many phases to the work handled by the industrial engineers of the Research Council. The scope of the service encompasses aid of a technical nature to both industry and government, provincial representation of Technical Information Service partly supported by a grant from the National Research Council, engineering advice and assistance given to other sections of Council, and the engineers have been made increasingly responsible for the planning and organization of the new building. In addition to these functions the Industrial Engineering Services section is planning research of an engineering nature on butane and will continue to perform tests on a fee basis for industries which request them.

Industrial Development

As the engineers of the section contact industries throughout the province, one of their main functions is to encourage growth of established industry and to assist in developing new industry. Often it is possible to do this by producing technical information or by contact with mutually co-operative individuals and companies, or by reference to the proper department of the Alberta Government.

In addition the industrial engineers often are of considerable assistance to the Industrial Development Branch of the Department of Economic Affairs in treating industrial inquiries, particularly from the technical point of view. This year the senior engineer took an active role in preparation of the report on industrial minerals for the Gordon Royal Commission on Alberta's Economic Prospects. Other industrial development has been carried out in the form of interviews with industrialists or replies to their correspondence. Inquiries often are received directly by the office, in which case liaison with officials of the Provincial Industrial Development Branch is made to keep them informed of these new developments. Examples of inquiries pertaining to this phase of the work include the manufacture of carbon dioxide, oil workers' safety helmets, monoethanolamine glycol, cement mill placement, manufacture of alum, and the adaptation of a closed-down cannery for other purposes.

The Provincial Marketing Board utilizes the services of the three industrial engineers in evaluating, from the technical aspect, the potential for new industrial developments which ought to be encouraged in Alberta. It is expected that this work will continue at an even higher level throughout the year as new industries develop throughout Alberta at an ever-increasing rate.



(Alberta Government Photo)

Industrial engineers discussing technical problems with industry.

Technical Information Service

Since responsibility for the field operations of Technical Information Service (T.I.S.) in Alberta was assumed by the Industrial Engineering Services section of the Research Council three years ago, this activity has become an ever more important part of the work, with all three engineers participating. Though industry itself was not contacted by the engineers as frequently as previously, largely due to moving into the new building, more industries called on the Research Council during the year. Lists have

been screened to a certain extent, so that the service is of more use to those industries included on the calling schedule. Through the year (October 1954 to September 1955) 808 calls were made and 566 inquiries were treated; roughly one-half of the inquiries were submitted to Ottawa and the balance treated locally from our own sources.

Some examples of inquiries handled by Technical Information Service are:

(1) Prevention of corrosion in underground storage tanks for chemicals,
(2) Assistance to a distillery in disposing of plant wastes,
(3) Selection of a suitable filter for a used-oil reclamation firm,
(4) The control of dust in cement plants,
(5) Mineral resources in Alberta,
(6) Prevention of zinc oxidation on galvanized steel.

The above inquires and many others were received from various industries in the province. Among these were metal trades, woodworking shops, chemical plants, mineral development companies and building material manufacturers. An attempt has been made to determine which type of industry utilizes T.I.S. to the greatest extent, but there appears to be no group which predominates in this respect. The service is used by plants of all sizes from those employing one man to the largest in the province, including organizations which have large research staffs and their own sources of information.

In addition to individual plant calls, a successful innovation for making the service more effective has been tried on several occasions. Some special groups were invited to attend evening meetings where these industries were difficult to approach during a normal work-day or otherwise were of marginal T.I.S. importance. Certain one-man concerns find difficulty in separating themselves long enough from their occupation to respond to a normal T.I.S. approach. The program for the meetings was developed to interest these people and consisted of a description of the function of T.I.S., examples of inquiries treated, an outline of some recent article pertaining to the industry, and usually the showing of films. The selection of films has been made easier through the co-operation of the Extension Department of the University of Alberta. Film types were Steel Making, Safety, Management, and Welding Techniques. An invitation was extended at each meeting to submit technical problems to the Research Council of Alberta.

Three such meetings were held, two in Edmonton and one in Calgary, and were attended by representatives of firms in the fields of sheet metal, machining and welding. The results of these meetings were encouraging, and the section expects to extend invitations to other such groups with common industrial problems.

Two members of the staff attended the annual conference of Technical Information Service in Toronto, September 26th to October 1st. Meetings were held at the Ontario Research Foundation which organized the conference this year very successfully. In addition to technical sessions during which the delegates discussed their regional problems and the problems of technical administration throughout Canada, plant tours were arranged through several of Ontario's larger industries.

Testing and Research

The section carries on a limited amount of testing and research for industries which request this service, on a fee basis. Examples of the work carried on last year are:

(1) Analysis of stresses by strain gage, in an overhead loader subjected to impact and suddenly applied forces;
(2) Investigations of noise characteristics in domestic furnaces (carried on in conjunction with the Physics Department of the University);
(3) Investigations on failure of double-glazed windows;
(4) Temperature measurements on equipment in the Royal Alexandra Hospital;
(5) Study of corrosion on metal jar rings;
(6) Tests to enhance settling of distillery wastes.

In the latter project there was active participation by other departments of the Research Council.

This activity is expected to increase considerably when the industrial engineers have the use of their own laboratory in the new building. In addition, it is expected that further co-operative research and testing will be done with other departments of the University.

Research Council Building

The attention to planning and construction details in connection with the new building proved to be a major activity of the industrial engineers. This function included the organization and design of the fixed furniture, and working out specifications and requirements for the purchasing of moveable furniture, machine shop equipment, and a variety of other prominent building items. Liaison was maintained between the Research Council and the Department of Public Works in accommodating the numerous requirements of all staff members.

Ceramics

The ceramics laboratory will be established on a permanent basis in the new building. Much of the necessary equipment has already been procured, and the remainder will be installed during the coming year. Numerous inquiries of a ceramic nature were answered, including the evaluation of a refractory lining in a heat-treating furnace and investigation into the cause of scumming on bricks during manufacture. Because of dislocation of facilities during the move to the new building, no laboratory investigations have been undertaken in recent months. It is expected that the coming year will permit some field and laboratory work to be continued.

Special Projects

The industrial engineers are requested often to undertake special projects. These included investigations in consultation with the University of Chicago and the National Research Council for setting up a station in the Rocky Mountains, suitable for taking cosmic ray measurements; assisting the coal section in the design of new apparatus to measure the grindability of coal, and in advising on coal utilization publications; conducting an investigation on the merits of a new oil-well pump; and assistance in an advisory capacity to the many project committees set up by the Council for industrial and government work.

Publications

A paper on calculating machines was published in the Engineering Journal and an affirmative notice has been received that a paper on strain gage analysis will be published shortly in the same journal.

Butane Research

Butane is at present in abundant supply. More is being produced than can be used by industry and it has become necessary especially during the summer months to flare some of this material. When the Trans-Canada pipe line is completed, those areas producing natural gas will have as a by-product tremendous quantities of butane. It is expected that some chemical industries will be set up to use butane in the manufacture of rubber or other products. However, it is unlikely that these industries will absorb all of the butane produced, according to estimates, and it will be necessary to develop other uses.

A symposium on the use of propane and butane for farm tractors was held this year to acquaint the manufacturers of farm equipment and other interested parties with a proposed research program on butane utilization. This research involves the design of equipment to permit local use of butane for engines, especially during cold weather. At the present time there is no effective method of utilizing this product when the temperature is below 32°F. Highlights of the symposium involved a discussion by representatives of an oil company, the Department of Agricultural Engineering and the Edmonton Transit System. It is proposed that the findings of this research will be publicized in co-operation with the Agricultural Engineering Department of the University.

BIOLOGICAL CYCLES

The current year has been notable for the continued paucity of the cyclic animal populations throughout central and northern Alberta. This year 55 samples have been submitted to the Provincial Veterinary Laboratory, in contrast to 753 in 1952; much greater collecting effort was involved this year, and most of the samples were obtained this past fall, following a very favorable summer.

While ruffed and sharp-tailed grouse, Hungarian partridges, snowshoe and jack rabbits (and magpies apparently with them) have conformed to the expected pattern and have shown a slight upswing during the past summer, the pheasant remains difficult to assess. It is now comparatively abundant, but it did not suffer the drastic reduction of the other species.

It is of interest to note that the current period of "crash" has coincided with the extensive predator extermination campaign carried on for two and a half years through central Alberta by the Provincial Game Branch and Department of Agriculture. Theoretically this must be assumed to have been in favor of recovery of the common game species, including hares and grouse, yet there is no evidence that there has been any such coincidence.

Under the circumstances the main activity of the year has consisted of visits to areas in Alberta from which recovery in numbers has been reported during the season. In view of the divergent views held by individual observers on scarcity and abundance, it was thought expedient to apply known criteria wherever the chance offered. Visits have consequently been paid to the Macleod and Lethbridge areas, the annually censused Westlock-Flatbush region, Athabasca, Anzac and numerous points nearer home, as well as the Cold Lake district.

Sample patches at Cooking Lake, now accurately censused annually for a period of years with the help of parties of students, support the general

impression throughout central Alberta that there has been a turn in the tide of numbers. The highest populations at present seem to be in southeast Alberta, but compared with usual peak numbers as they occur in central Alberta, the supply is at best medium, with the possible exception of the pheasant.

Publications

The pamphlet, The Ten-Year Cycle, is now in process of revision and enlargement, and is to be re-issued during the winter by the Department of Extension of the University.

Acknowledgments

This investigation is again indebted to the continued co-operation of the Provincial Veterinary Laboratory, the Provincial Game Department, and numerous collaborators scattered throughout the province.

ANIMAL SCIENCE

The following investigation in the Department of Animal Science of the University has been supported by the Research Council:

Factors Affecting the Percentage Hatch of Turkey Eggs

The experiments conducted this year included a repetition of the study on the effect of body fleshing and carriage of the male on fertility and hatchability of turkey eggs, conducted in 1954, which showed that the use of upstanding males in the breeding pens resulted in improved fertility of eggs produced. The study was extended to determine whether or not the addition of certain known vitamins and unidentified factors was necessary for improved productive performance. The results obtained this year confirmed those obtained in 1954. The use of upstanding males in the breeding pens resulted in improved fertility of eggs produced, as compared to eggs produced in the pens in which front-heavy toms were used. Comparison of the performance of the breeders fed the breeding ration with and without the addition of certain known vitamins and unidentified factors, indicated that the removal of these had no observable effect on reproductive performance. It would, therefore, appear that their addition was not necessary under the experimental conditions employed.

SOLAR ULTRAVIOLET RADIATION

The monochromator mentioned in last year's report has been received by the Physics Department and tested. An auxiliary electrometer is required for the measurement of the extremely small photo-currents when the spectral response of the various photo-cells is studied. This will be available for part-time use in the Solar Ultraviolet Standardization program.

A supplementary grant of about $300.00 has been made available for this work from UNESCO funds through the Radiation Commission of the International Association of Geodesy and Geophysics. This grant will assist in the standardization program referred to last year, and will be spent on German-type radiation equipment to help tie together European and American measurements in the ultraviolet, and on other equipment needed for the program.

The observations being made with Council's equipment at the Edmonton Airport are continuing. When data for a few years more than a sunspot cycle (eleven years) are available, a full analysis for comparison with ozone and

with biological cycles can be made. Meantime, the research in this province is contributing a share to the program of the above-mentioned International Association.

HAIL STUDIES

An informal committee, during the last year, held several meetings on the subject of hail which represents a particularly serious problem in Western Canada. Hail damage not only causes widespread economic loss, but its frequent occurrence in certain areas adversely affects agriculture in those regions. Studies of attempts at inducing precipitation, while dubious in themselves, do suggest that there may be some possibility of reducing the occurrence of hail. A Council representative and a University representative attended a meeting on hail in Toronto, called by the Meteorological Service of Canada. The deliberations at that meeting indicated the need for basic information on cloud formation and the whole problem of the physics of the upper atmosphere. Since Alberta has regions that have experienced hail damage in seven out of ten years, it would appear that such areas are almost ideal locations for a scientific appraisal of the factors responsible for hail incidence. Full information on appropriate scientific approaches to the hail problem are being assembled and will be used in the planning of further action.

INDUSTRIAL POLLUTION COMMITTEE

Pollution problems were not encountered during the past year and consequently there was no need for investigational activity. However, the chairman and several members of the committee held informal conversations and are aware that the need for specific pollution studies may be encountered at any time. There is an ever-increasing national and international interest in the pollution problem, and this tends to stress the importance of being ready to take prompt action. In view of all the circumstances, the committee continues to stand and thus is prepared to face any emergent pollution matter or institute work along lines of possibly forestalling the development of a specific problem.

LIST OF PUBLICATIONS

of

RESEARCH COUNCIL OF ALBERTA

EDMONTON, ALBERTA

Requests for publications should be addressed to the Librarian, Research Council of Alberta, University of Alberta, Edmonton, Canada.

ANNUAL REPORTS OF COUNCIL

No. 3 (for the calendar year 1920); pp. 36. (Out of print.)
No. 5 (for the calendar year 1921); pp. 86. (Out of print.)
No. 8 (for the calendar year 1922); pp. 64. (Out of print.)
No. 10 (for the calendar year 1923); pp. 76. (Out of print.)
No. 12 (for the calendar year 1924); pp. 66. **Price 35 cents.**
No. 16 (for the calendar year 1925); pp. 65. **Price 35 cents.**
No. 20 (for the calendar year 1926); pp. 53. **Price 25 cents.**
No. 22 (for the calendar year 1927); pp. 49. **Price 25 cents.**
No. 24 (for the calendar year 1928); pp. 53. **Price 35 cents.**
No. 25 (for the calendar year 1929); pp. 65. **Price 35 cents.**
No. 26 (for the calendar year 1930); pp. 76. **Price 35 cents.**
No. 27 (for the calendar year 1931); pp. 53. (Out of print.)
Nos. 28, 29 and 32 (for the calendar years 1932-1934); pp. 90. **Price 35 cents.**
No. 33 (1935); pp. 43. **Price 35 cents.**
Nos. 37-43 (for 1936-42). (Not published.)
No. 44 (1943); pp. 14. **Price 5 cents.**
No. 45 (1944); pp. 18. **Price 5 cents.**
No. 47 (1945); pp. 21. **Price 5 cents.**
No. 50 (1946); pp. 28. **Price 5 cents.**
No. 51 (1947); pp. 28. **Price 5 cents.**
No. 54 (1948); pp. 27. **Price 5 cents.**
No. 55 (1949); pp. 26. **Price 5 cents.**
No. 60 (1950); pp. 39. **Price 5 cents.**
No. 62 (1951); pp. 31. **Price 5 cents.**
No. 64 (1952); pp. 40. **Price 5 cents.**
No. 66 (1953); pp. 41. **Price 5 cents.**
No. 69 (1954); pp. 47. **Price 5 cents.**
No. 73 (1955); pp. 52. **Price 5 cents.**

REPORTS—COAL

No. 10A (1923); COMBUSTION OF COAL FOR THE GENERATION OF POWER, by C. A. Robb. (Out of print.)

No. 14 (1925); pp. 64. ANALYSES OF ALBERTA COALS, with 18 maps and two charts, by Edgar Stansfield, R. T. Hollies and W. P. Campbell. (Out of print.)

No. 35 (1944); pp. 174. COALS OF ALBERTA—THEIR OCCURRENCE, ANALYSIS AND UTILIZATION, by Edgar Stansfield and W. Albert Lang. In six parts.

Parts I-V—Occurrence, classification, production, special tests, general properties, preparation, utilization and combustion. (Out of print.)

Part VI—Analytical and technical data by coal areas. **Price 50 cents.**

No. 46. ALBERTA COALS AND AUTOMATIC DOMESTIC STOKERS. Edgar Stansfield and Colin A. Genge. **Price 20 cents.**

No. 65; REVISED COALS OF ALBERTA. (In preparation.)

REPORTS—PETROLEUM

No. 18; THE BITUMINOUS SANDS OF ALBERTA, by K. A. Clark and S. M. Blair.

Part I (1927)—Occurrence, pp. 74. (Out of print.)

Part II (1927)—Separation, pp. 36. (Out of print.)

Part III (1929)—Utilization, pp. 33. (Out of print.)

No. 53 (1949); THE ROLE OF VERY FINE MINERAL MATTER IN THE HOT WATER SEPARATION PROCESS AS APPLIED TO ATHABASCA BITUMINOUS SAND, by K. A. Clark and D. S. Pasternack; pp. 22. **Price 15 cents.**

No. 57 (1950); DETERMINATION OF VISCOSITIES AND SPECIFIC GRAVITIES OF THE OILS IN SAMPLES OF ATHABASCA BITUMINOUS SAND, by S. H. Ward and K. A. Clark; pp. 21. **Price 15 cents.**

No. 58 (1951); THE COMPONENTS OF THE BITUMEN IN ATHABASCA BITUMINOUS SAND AND THEIR SIGNIFICANCE IN THE HOT WATER SEPARATION PROCESS, by D. S. Pasternack and K. A. Clark; pp. 14. **Price 15 cents.**

REPORTS—SOILS

No. 23 (1930); PRELIMINARY SOIL SURVEY ADJACENT TO THE PEACE RIVER, ALBERTA, WEST OF DUNVEGAN, by F. A. Wyatt and O. R. Younge; pp. 33 and colored map. Scale one inch to four miles. (Out of print.)

No. 31 (1935); PRELIMINARY SOIL SURVEY OF THE PEACE RIVER - HIGH PRAIRIE - STURGEON LAKE AREA, by F. A. Wyatt; with colored map. Scale one inch to four miles. (Out of print.)

No. 56 (1950); SOIL SURVEY OF THE RYCROFT AND WATINO SHEETS, by Wm. Odynsky and J. D. Newton; pp. 84 and two maps.

No. 63 (1953); SOIL SURVEY OF THE HIGH PRAIRIE AND McLENNAN SHEETS, by Wm. Odynsky, A. Wynnyk and J. D. Newton.

REPORTS—GEOLOGY

No. 1 (1919); FIRST ANNUAL REPORT ON THE MINERAL RESOURCES OF ALBERTA, by J. A. Allan; pp. 104. **Price 25 cents.**

No. 2 (1920); SECOND ANNUAL REPORT ON THE MINERAL RESOURCES OF ALBERTA, by J. A. Allan; pp. 138+14. (Out of print.)

No. 4 (1921); GEOLOGY OF THE DRUMHELLER COAL FIELD, ALBERTA, by J. A. Allan; pp. 72 and 6-color map (Serial No. 1). (Out of print.)

No. 6 (1922, Part I); GEOLOGY OF THE SAUNDERS CREEK AND NORDEGG COAL BASINS, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 76 and 2-color map (Serial No. 2). (Out of print.)

No. 7 (1922, Part II); AN OCCURRENCE OF IRON ON THE NORTH SHORE OF LAKE ATHABASCA, by J. A. Allan and A. E. Cameron; pp. 40; two maps (Serial Nos. 3 and 4). (Out of print.)

No. 9 (1923); GEOLOGY ALONG BLACKSTONE, BRAZEAU AND PEMBINA RIVERS IN THE FOOTHILLS BELT, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 48 and 6-color map (Serial No. 5). (Out of print.)

No. 11 (1924); GEOLOGY OF THE FOOTHILLS BELT BETWEEN McLEOD AND ATHABASCA RIVERS, ALBERTA, by R. L. Rutherford; pp. 61 and eight-color map (Serial No. 7). Scale one inch to two miles. (Out of print.)

No. 13 (1945); GEOLOGY OF RED DEER AND ROSEBUD SHEETS, by J. A. Allan and J. O. G. Sanderson; pp. 109. Two geological maps in 8 colors. Scale one inch to three miles. Serial No. 8, Red Deer Sheet, and Serial No. 9, Rosebud Sheet, now out of print. Replaced by Map No. 9A, combination of Maps No. 8 and 9. Scale one inch to four miles. **Price 75c.**

Map No. 10 (1925); GEOLOGICAL MAP OF ALBERTA, by J. A. Allan. In 14 colors. Scale one inch to 25 miles. (Out of print.)

No. 15 (1926); GEOLOGY OF THE AREA BETWEEN ATHABASCA AND EMBARRAS RIVERS, ALBERTA, by R. L. Rutherford; pp. 29 and three-color map (Serial No. 11). (Out of print.)

No. 17 (1927); GEOLOGY ALONG BOW RIVER BETWEEN COCHRANE AND KANANASKIS, ALBERTA, by R. L. Rutherford; pp. 46 and nine-color map (Serial No. 12). Scale one inch to one mile. (Out of print.)

No. 19 (1928); GEOLOGY OF THE AREA BETWEEN NORTH SASKATCHEWAN AND McLEOD RIVERS, ALBERTA, by R. L. Rutherford; pp. 37 and three-color map (Serial No. 13). Scale one inch to three miles. **Price 10 cents.**

No. 21 (1930); GEOLOGY AND WATER RESOURCES IN PARTS OF PEACE RIVER AND GRANDE PRAIRIE DISTRICTS, ALBERTA, by R. L. Rutherford; pp. 80 and six-color map (Serial No. 14). Scale one inch to four miles. (Out of print.)

No. 30 (1934); GEOLOGY OF CENTRAL ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 41 and 10-color map (Serial No. 15). Scale one inch to ten miles. (Out of print.)

Map No. 16 (1937); GEOLOGICAL MAP OF ALBERTA (colored), by J. A. Allan. Scale one inch to 16 miles. (Out of print.)

Map No. 17 (1939); GEOLOGICAL MAP OF ALBERTA (black and white), by J. A. Allan. Scale one inch to 32 miles. **Price 5 cents.**

Map No. 18 (1940); COAL AREAS OF ALBERTA, by J. A. Allan. Scale one inch to 20 miles. **Price 25 cents.**

No. 34 (1943), in five parts, by J. A. Allan; pp. 202.

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