Report No. 62.

THIRTY-SECOND
ANNUAL REPORT
OF THE
RESEARCH COUNCIL OF ALBERTA
1951

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The following report, the Thirty-Second Annual Report of the Research Council of Alberta, was submitted in March, 1952, by Dr. N. H. Grace, Director of Research, to the Chairman of the Council, The Honourable N. E. Tanner, Minister of Mines and Minerals. The Chairman submitted the report to the Premier of Alberta, The Honourable E. C. Manning, who tabled it in the legislature.

The offices and laboratories of the Council are situated in the buildings of the University of Alberta. Requests for information and reports should be addressed to the Secretary, Research Council of Alberta, University of Alberta, Edmonton, Canada.

MEMBERS OF COUNCIL

The Honourable N. E. Tanner, Minister of Lands and Forests and Minister of Mines and Minerals, Chairman.

The Honourable E. C. Manning, Premier of Alberta.

The Honourable Dr. J. L. Robinson, Minister of Industries and Labour.

Dr. Andrew Stewart, President, University of Alberta.

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†Dr. N. H. Grace, Director of Research.

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Mr. O. C. McIntyre, Edmonton.

Mr. R. D. Purdy, Calgary.

Mr. F. V. Seibert, Edmonton.

*Retired as Director of Research, July, 1951.
†Appointed Director of Research, October, 1951.

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

The offices and laboratories of the Council are in the University of Alberta. The Secretary of Council is W. A. Lang.

TECHNICAL ADVISORY COMMITTEE

Dr. N. H. Grace, Director of Research, Chairman.

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Dr. J. D. Newton, Professor of Soils, the University.

Dr. P. S. Warren, Professor of Geology, the University.

Mr. W. A. Lang, Secretary of Council, Secretary.

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   Prof, J. A. Harle, Department of Electrical Engineering, the University.
   Mr. W. C. Whittaker, representing The Western Canada Bituminous Coal Operators' Association.
   Mr. J. A. Davidson, representing The Domestic Coal Operators' Association of Western Canada.

   B. Petroleum and Natural Gas:
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   Dr. G. W. Govier, Department of Chemical Engineering, the University.
   Prof. J. A. Harle, Department of Electrical Engineering, the University.
   Mr. J. S. Charlesworth, Gasoline and Oil Testing.
   Representative from Western Canada Petroleum Association, to be appointed.

2. *Industrial Projects*:
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   Mr. R. Martland, Director, Industrial Development and Economic Research, Department of Economic Affairs.
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   Mr. J. Gregory, Industrial Engineer.

3. *Surveys,* Dean R. M. Hardy, Co-ordinating Chairman.

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   Dr. P. S. Warren, Department of Geology, the University, Chairman.
   Mr. M. B. B. Crockford, Petroleum and Natural Gas Conservation Board.
   Dr. R. D. T. Wickenden, Federal Geological Survey.
   Mr. G. A. Collins, Geologist.

B. Soils:

Dr. J. D. Newton, Department of Soils, the University, Chairman.

Mr. O. S. Longman, Deputy Minister, Department of Agriculture.

Mr. V. A. Wood, Director of Lands, Department of Lands and Forests.

Mr. W. E. Bowser, Federal Experimental Farms Service.

Mr. W. Odynsky, Soil Surveyor.

C. Highways:

Dean R. M. Hardy, Faculty of Engineering, the University, Chairman.

Mr. L. H. McManus, Assistant Chief Construction Engineer, Department of Highways.

Mr. Hugh Miller, representing the Alberta Section of the Prairie Road Builders' Association.

STAFF OF THE RESEARCH COUNCIL

The following held full-time appointments on the technical staff during the year:

N. H. Grace, Director of Research, from October.
Robert Newton (part), Director of Research, to July.
W. A. Lang, Senior Research Chemist, Coal, and Secretary of Council.
D. S. Pasternack, Senior Research Chemist, Bituminous Sands.
J. S. Charlesworth, Chemist, Gasoline and Oil Testing.
Wm. Odynsky, Soil Surveyor, Soils.
G. W. Hodgson, Research Chemist, Bituminous Sands.
Donald Quon (part), Research Engineer, Natural Gas.
John Gregory, Industrial Engineer, Industrial Projects.
W. H. A. Clow, Geologist, Geology, to February.
G. A. Collins, Assistant Geologist, Geology, from May.
Edward Tipman, Asst. Chemist, Gasoline and Oil Testing.
J. S. C. Dunn, Asst. Research Engineer, Coal.
T. E. Morimoto, Asst. Research Engineer, Coal.
Mr. R. Wardle, Asst. Research Chemist, Coal.
J. F. Fryer, Asst. Chemist, Coal.
J. L. Carveth, Asst. Research Engineer, Coal.
Andrew Wynnyk, Asst. Soil Surveyor, Soils.
A. G. Swan, Asst. Geologist, Geology, from May.
M. D. Scheeler, Asst. Soil Surveyor, Soils.
S. J. Groot, Draftsman-Compiler.

The following held full-time appointments on the non-technical staff during the year:

Miss K. S. Wark, Accountant-Librarian.
Miss S. M. Mackintosh, Technical Stenographer.
Mrs. N. A. Luck, Stenographer, to April.
Miss J. K. Christensen, Stenographer, from May.
Mrs. B. Johnson (part), Stenographer, from October.
Leonard New, Laboratory Assistant, Gasoline and Oil Testing, to February.
R. H. Wood, Laboratory Assistant, Gasoline and Oil Testing, February to September.
Miss G. M. Rymer, Laboratory Assistant, Gasoline and Oil Testing, from October.
H. R. Van der Meulen, Laboratory Assistant, Coal, to February.
Wm. G. Navis, Laboratory Assistant, Coal, February to April.
Hans Rempis, Laboratory Assistant, Coal, from May.
Olaf Katzer, Laboratory Assistant, Coal, to September.

The following held temporary appointments during the year:

Edward L. Alexander, Research Assistant, Bituminous Sands, February 1-April 30.
R. W. Bruce, Research Assistant, Bituminous Sands, May 1-August 31.
E. B. Cooper, Soils Assistant, May 1-September 30.

F. J. Disney, Cook, Soils, July 1-September 23.
A. M. F. Hennig, Soils Assistant, from May 18.
R. A. Hill, Soils Assistant, May 7-September 23.
Miss Elspeth W. L. Mainland, Research Assistant, Natural Gas, May 15-September 15.
H. Meronek, Research Assistant, Natural Gas, May 15-Sept. 11.
K. Stewart, Soils Assistant, May 1-September 30.

The following members of the Faculty of the University of Alberta assisted in the work of the Council:

Dr. K. A. Clark, Oil Sands.
Dr. E. H. Gowan, Dr. K. B. Newbound, Ultra-Violet Solar Radiation.
Dr. G. W. Govier, Natural Gas Research.
Dean R. M. Hardy, Highway Research.
Dr. J. D. Newton, Soil Survey.
Dr. Wm. Rowan, Biological Cycles.

ANNUAL REPORT

OF THE

Research Council of Alberta

1951

This report describes the work of the Council during the calendar year 1951. The projects under study in 1950 were continued, particular problems were completed and certain new ones commenced. Encouraging progress has been achieved, although procurement of suitable summer help, staff turnover and limitations as to space were among the difficulties encountered. The Council's broad program, mainly of applied research directed to the fuller utilization of the natural resources of Alberta, owes much to the careful and critical guidance of the various advisory committees.

The oil sands project considered such engineering and chemical problems as the movement of sand through hoppers, its flow as a suspension, and the content of vanadium, sulphur and porphyrin in the oil. The members of the staff contributed substantially to the Oil Sands Conference and were responsible for editing the Proceedings of these meetings. A balanced program on coal was maintained; chemical studies included an expanded analytical program preparatory to the revision of Research Council of Alberta Report No. 35, and fundamental studies on coal constitution; engineering problems dealt with the application of the cyclone washer with heavy media, physical properties of media, balling and briquetting of fine coals, and moisture retention on washing. The Gasoline and Oil Testing Laboratory conducted a survey of Alberta gasolines, made tests for various government departments, investigated the viscosity at low temperature of lubricating oils under dilution, and initiated studies on the effect of storage time on gum formation in gasoline. Two geologists were appointed in the spring of 1951; their program included the mapping of surface deposits in the St. Ann area and investigation of economic and industrial minerals. Special attention was directed to clays, sands, gravels and carbonate rocks. Equipment has been acquired for the differential thermal analysis of clays and carbonate rocks. The highway research program included study of slides located at the north approach of the Dunvegan ferry, the north approach of the Smith bridge, and at a location involving the highway and railway close to Lundbreck. The Industrial Projects section rendered technical assistance to government and industry. Natural gas studies involved three main problems: pyrolysis, partial oxidation of butane, and formation of carbon black. The Research Council Soils' staff continued the Alberta soils survey in co-operation with the soils' staff of the Dominion Experimental Farm Services, and the Department of Soils, University of Alberta. The Council's staff

were primarily concerned with checking the soils in the High Prairie and McLennan sheets preparatory to the publication of a report, and with detailed surveys of the Wm. Pearce, the Sturgeon Lake and Edmonton areas. The investigation of biological cycles dealt with the wide fluctuation in the population of wild life in these northern latitudes. Periodic peaks in wild life populations may be related to fluctuations in the ultra-violet solar radiation now recorded by means of a thorium photocell in the Edmonton region.

Reports of mimeographed circulars published during the year include:

Report No. 58 (1951): "The Components of the Bitumen in Athabasca Bituminous Sand and Their Significance in the Hot Water Separation Process", D. S. Pasternack and K. A. Clark, pp. 14.

Report No. 59 (1951): "Geology of Carbondale River Area, Alberta", W. H. A. Clow and M. B. B. Crockford, pp. 70 and 11-color map (serial No. 22).

Report No. 60 (1951): "Thirty-First Annual Report of the Research Council of Alberta, 1950", pp. 39.

Report No. 61 (1951): "Clay Deposits of the Elkwater Lake Area of Alberta", M. B. B. Crockford, pp. 102 and 2-color map (serial No. 23).

Report on Public Lands Open for Settlement in the Peace River District, Alberta, Wm. Odynsky and V. A. Wood (report prepared in conjunction with Department of Lands and Forests).

Circular No. 11, Alberta Motor Gasoline Survey, 1951, J. S. Charlesworth and E. Tipman.

In addition, members of the staff contributed some fourteen papers to the scientific literature, and four Master of Science theses were submitted to the University of Alberta on investigations sponsored by the Council. A list of the major publications of the Council since its inception is given as an appendage to this report.

Acknowledgement is here made of the retirement of Dr. Robert Newton as Director of Research, and the appointment of Dr. N. H. Grace to that position.

Thankful acknowledgement is made of the co-operation and assistance extended to the Council by government and University departments and by many industrial concerns.

OIL (BITUMINOUS) SANDS

Again, this year, the Council staff concerned with bituminous sand studies devoted much of its time to assisting the Board of Trustees, Oil Sands Project. The Board sponsored the Athabasca Oil Sands Conference. Preparation for the conference and the editing of the Conference Proceedings were major items in the program of the Research Council staff. However, good progress was made with the laboratory studies.

It is the considered opinion of those concerned with the cause of oil sand development that the term "bituminous sand" and "tar sand" should be dropped. They both imply that the oil sands do not contain petroleum. This implication is false and has a bad

influence from the standpoint of development. The proper term to use is "oil sands". This term is used in the text of this report.

Athabasca Oil Sands Conference

The Board of Trustees, Oil Sands Project, released its "Report on the Alberta Bituminous Sands" by S. M. Blair (generally referred to as the "Blair Report") in December, 1950. This report has been received with much interest by the oil industry. A thousand copies have been distributed in meeting requests for it and an additional five hundred copies have been printed. As a follow-up of the Blair report and of the interest shown in the possibilities of oil sand development, the Board of Trustees decided to hold a conference. The conference took place in Edmonton during September 10-15. About one hundred and twenty delegates representing oil companies and government departments attended. Three days were spent at technical sessions on the university campus. Papers and discussion covered the geology of the oil sand deposit and the various steps involved in mining the oil sand, processing it and transporting the final oil product to market. Following the technical sessions about seventy-five delegates went to McMurray and Bitumount to see the oil sands and the government plant at first hand. Delegates were generous in their expressions of appreciation of the conference. There can be no doubt that it resulted in a substantial advance toward the goal of oil sand development.

Laboratory Studies

Vanadium in the Oil Sand

Like many other heavy crude petroleums, the oil in the Alberta oil sands contains appreciable quantities of vanadium and other trace minerals. Because of the detrimental action of vanadium in catalytic processes employed in petroleum refining, attention has been directed to elucidating the manner in which vanadium occurs in the oil sand. Vanadium is believed to occur both as a mineral and as a component of the oil itself. Laboratory investigations have confirmed the mineral occurrence and have indicated that about half of the total vanadium content can be attributed to this factor. The other half of the vanadium has been found distributed throughout the oil. Solvent and chromatographic fractionation of the oil component of the oil sands showed that the metal appeared to be more concentrated in the resin and asphaltene fractions than in the light oils. There is reason to believe that all the vanadium attributed to the asphaltene fraction is, in reality, in finely divided mineral material associated with that component of the oil. The vanadium in the resin fraction is probably associated with a porphyrin-type material shown by spectrophotometric means to exist therein. The porphyrin compound is similar to one found in other oils, notably oil from Santa Maria Valley in California.

Origin of the Oil Sands

Geologists are divided on the question of the origin of the Alberta oil sands. Not only is the question of the source of the oil undecided, but a divergence of opinion exists concerning the manner of deposition of the sand beds themselves. It is reasonable to believe that chemical analytical methods would afford a direct approach to the correlation of oil-sand oil with other Alberta oils.

One method of correlation is based on the use of marker components of oils. Porphyrin compounds have been used as markers, and they are particularly applicable because of the simplicity of the analytical methods involved. A preliminary study has indicated a close correlation between Athabasca oil and Lloydminster oil. Similar examination of a typical Devonian oil showed an absence of porphyrin compounds therein. It is therefore suggested that a common origin for the Cretaceous and Devonian oils is not likely.

Characteristcs of the Flow of Sand Suspensions

In the design and operation of any plant processing Alberta oil sands consideration must be given to methods for disposing of the waste sand. For every barrel of oil produced more than a ton of sand must be wasted. Although transportation by conveyor belt has been used to a limited extent, it is believed that pipeline transportation is more suitable from a practical and economic point of view. In the pipeline method the waste sand is dispersed in water and the suspension so formed is pumped to the disposal area. It is apparent, therefore, that the disposal method is resolved into two parts: the production of a suspension of the sand, and the pumping of the suspension.

The production of the suspension is closely related to the problem of controlling the egress of sand from the separation plant system. Laboratory-scale apparatus was assembled to simulate a separation cell and its sand pump. A simple system for controlling the removal of sand from a bed of sand maintained in the cell was designed and proven. A rotating unit in the sand bed served as a detector of the sand level and acted through a conventional control instrument to vary the flow of raw water to the sand pump in such a way that the flow of sand from the sand bed to the pump was hindered to a greater or lesser extent. A secondary observation concerning the operation of the laboratory-scale apparatus was that the junction of the sand and water streams caused violent agitation of the sand in the sand bed, well above the point at which the streams join one another.

The flow of the sand suspensions in a pipeline was of considerable interest because improper conditions of flow could cause undue power consumption and in the extreme could make the pipeline inoperative. Attention was directed to a study of the friction factor of sand suspension in pipes. It was found that at high rates of flow the movement of sand suspensions was essentially the same as for homogeneous fluids. At low flows, indicated by low Reynolds' numbers, the friction factor observed for sand suspensions was abnormally high. It was shown that the abnormal values were a result of sand settling out of suspension and that the settling occurred until the sand accumulated in the test pipeline to such an extent that the turbulence of flow in the restricted pipe was sufficient to stabilize the suspension entering the system. Pipeline transport was employed at Bitumount. Suitable pipeline design was achieved by trial-and-error methods but showed substantial agreement with what would be predicted by the results of the laboratory study with the smaller-scale system.

Electrothermal Treatment of Oil Sands

Recently the oil industry has become interested in the possibilities of electrically heating oil sands for purposes of secondary

recovery of oil from depleted oil fields. Several oil company laboratories that are working along this line have thought of electrical heating as an approach to the problem of winning oil from our oil sands "in situ". Inquiries for information about the oil sand formation and for oil sand samples for experimental work have been received.

An oil sand has high electrical resistance. Practically no current will flow through oil sand between electrodes in it that have ordinary differences of potential across them. If, however, the potential difference is increased sufficiently it is generally found that the electrical resistance of the oil sand breaks down and the oil sand becomes a conductor. Current then flows and heating of the oil sand results. This heating can be pushed to any desired degree from mere warming of the oil sand up to temperatures at which the oil distils and thermally decomposes.

There would appear to be an interesting possibility for electrically heating our oil sand. In our 1947 Annual Report it was reported, in connection with the displacement of oil from the oil sands by water-flooding, that at 150°F. water penetrates the oil sand and half of the oil is displaced before the ratio of water to oil in the flow becomes unduly high. However, this observation seemed to have no practical significance since no way of heating the oil sand beds "in situ" was apparent. Electrical heating provides a means for heating them to 200°F. at which temperature water-flooding would be more effective than at 150°F.

Some laboratory work was done during the past summer on the electrical resistance of our oil sand and on its breakdown under the influence of a high-potential difference. It was confirmed that high-potential electrical heating of the oil sand could be accomplished after breakthrough had been established.

Mining Oil Sand by the Block-Caving Method

The engineers of Fred Mannix & Co. who analysed the application and costs of open-pit mining of oil sand for the Blair report threw out the suggestion that underground mining by a modified block-caving method might be done at lower cost than by open-pit mining. Their idea was to maintain a steam atmosphere in stopes in the oil sand. The steam would raise the surface temperature of the stopes sufficiently to cause the oil sand to soften and flow. Thus, a hot oil-sand pulp would accumulate in the bottom of the stopes and could be withdrawn through a raise into a tunnel in the limestone below the oil sand formation. The scheme depended on whether or not oil sand will flow from a face when heated by transfer of heat from a steam atmosphere. The question was put to experimental test and it was found that no flow took place.

Some experimentation on the block-caving of repacked oil sand at room temperature was done. The indications were that for a given denseness of packing a stable arch formed, on under-cutting, up to a critical area. When under-cutting was more extensive than this critical area, the arch that formed was unstable and progressive caving occurred. During discussion of the topic of block-caving at the Oil Sand Conference it was stated that almost anything in the way of a natural mineral deposit will cave if sufficiently undercut. So the results of the block-caving experiments on oil sand were what were to be expected.

Movement of Oil Sand Through a Feed Hopper

There was an oil sand storage and feed hopper at the head of the separation plant at Bitumount. It worked well. But it is realized that we do not know enough about why it worked to provide a good basis for design of hoppers of some specified throughput. Experimental study of the factors that are operative in the functioning of an oil sand feed hopper is needed.

A start at studying what goes on when oil sand moves through a hopper was made during last winter and spring. The hopper used was an inverted pyramid with the apex so arranged that bottom openings of various cross-sectional areas could be provided. Between 300-600 lb. of oil sand were shovelled into the hopper and then a bottom opening was uncovered. With a smaller opening than 8″ square, a stable arch formed above the opening. In the case of the 8″ opening, however, the arch was not stable and material caved and fell away in an erratic unpredictable fashion. The caving increased the size of the arch until a stage was reached where a shear failure occurred creating an elliptical-shaped plug extending from the arch to the oil sand surface in the hopper. The material in the plug then ran out through the bottom opening at an accelerating rate. This action created a central cavity in the hopper into which the rest of the oil sand caved or slumped and then ran out. The discharge from the hopper was at an accelerating rate from the time of the shear failure onward provided that the hopper was not too full. When the hopper was more than so full, the slumping of oil sand into the central cavity was too rapid for all this material to run out freely. The bottom of the cavity then became filled over. When this happened, the discharge rate became constant.

The experimental work ceased as this stage. The worker left to resume his regular employment as a mining engineer in the North. Only a start was made at investigating the operation of a hopper such as that at Bitumount.

COAL

Analytical and Physical Tests

The analytical program of coal testing was materially increased in 1951 in preparation for the revision of R.C.A. Report No. 35, "Coals of Alberta—Their Occurrence, Analysis and Utilization." Through courtesy of the Department of Mines and Minerals, Provincial Mines Inspectors collected some 90 channel samples of coal from operating mines which had not been sampled previously or from which samples had not been taken since 1944. These samples were subjected to proximate, ultimate and calorific analysis. The data so obtained are being correlated with information already on file relative to Alberta coals and will be used in determining typical analyses for inclusion in the above-mentioned report. The Federal Department of National Defence submitted for analysis a number of samples of coal from consignments purchased by them for use at Army and Air Force camps. In addition, nine samples of dust collected from roadways in operating mines were tested in respect to their explosion hazard, and a large number of miscellaneous samples of coal and related materials were analysed in connection with other investigations of Council.

Constitution of Coal

The investigation of the oxidation of Alberta subbituminous coals was continued with a study of the absorption spectra of various oxidation degradation products in aqueous solution. A large part of the studies carried out on the constitution of coal have been reported in the form of a thesis submitted to the University of Alberta in partial fulfilment of the requirements of the degree of Master of Science.

The work so far has shown that Alberta subbituminous coals are readily attacked by oxygen, nitric acid, and alkaline potassium permanganate at temperatures below 100°C. and at atmospheric pressure to form humic acids similar to those obtained by alkali extraction of these coals. The ultimate composition of these humic acids corresponds very closely to that of humic acids produced in a similar fashion from older and higher rank coals from Pennsylvania.

Accompanying the humic acids from such oxidations are simpler compounds which are not only soluble in alkalis, but also in water over a wide pH range, in ethanol, and partially soluble in ether. As much as 50% or more of subbituminous coals may be converted to these soluble acids by mild nitric acid oxidation. Unlike the humic acids, they fuse even at low temperatures. They are characterized by a much lower carbon content (ca. 45%), and by a remarkably high oxygen content. They are not only extremely interesting by virtue of the light which they may throw on the chemical constitution of coal, but also because they might serve as starting materials for the manufacture of alkyd resins which are today exceedingly important industrially.

Absorption spectrophotometry, a powerful technique in the determination of the structure of large and complex molecules, has been applied to the study of the oxidation degradation products. Humic acids show considerable absorption of ultra-violet light. A striking property of the absorption spectra in the range 200 to 800 millimicrons of humic acids produced by various kinds of oxidation was the remarkable similarity of the curves. Not only are the humic acids similar in those properties which the absorption spectra reflect, regardless of the method of generation, but also humic acids from Alberta subbituminous coals are similar to those from Pennsylvania bituminous coals in this respect.

The absorption spectra of the soluble acids are similar to those of the humic acids. This further indicates the close relationship of these two classes of compounds. It has been shown from absorption spectra that these soluble acids can be fractionated to some extent chromatographically by columns of alumina. It should therefore be possible to obtain fairly homogeneous samples of the soluble acids by chromatographic separation techniques.

The optical density of aqueous alkaline solutions of soluble acids was found to be much less than the optical density of like solutions of the same concentration of humic acids. This relationship is in accordance with the view that the intensity of color of these organic acids is a function of the extent of oxidation from the original coal substance. The nature of these chromophoric groups, although it has attracted little attention, is certainly of great significance in any study of the chemical constitution of coal. Careful chromatographic fractionation of the soluble acids combined with spectro-

photometric examination shows considerable promise of revealing something of the nature of the color-producing groups and of the acid molecule as a whole. By means of such procedures it has been demonstrated that ketoenol tautomeric structures exist in the molecular configurations of the esters of certain of the soluble acids produced by alkaline permanganate oxidation.

Cleaning of Coal

The D.S.M. cyclone washer equipment, described in the 1950 Annual Report, was utilized to obtain fundamental data on the operating characteristics of the cyclone when cleaning coals with a high inherent mineral matter content such as are encountered in this province. In order that the number of operating variables could be kept at a minimum, only one type of coal was tested; this coal was medium volatile bituminous in rank. The heavy medium used was a suspension of finely ground magnetite in water.

A series of tests were made with the cyclone washer to investigate the influence of the following operating variables: underflow apex diameter, specific gravity of medium, pulp ratio of the slurry, specific gravity distribution of feed, and size analysis of the feed.

It was found that the sharpness of separation was not affected appreciably by variations in specific gravity of suspension or underflow apex diameter, providing that the specific gravity of separation was within the normal range of washing operation. The tests were made with smaller underflow apex diameters and lower specific gravity suspensions than had been recommended by workers at the Centre d'Etudes et Recherches des Charbonnages de France, who had made a study of some of the cyclone's operating variables. However, with a suspension specific gravity of only 1.30, separation specific gravities of 1.60 to 1.70 were obtained with good cleaning results.

Cyclone performance was not too adversely affected by decreasing the pulp ratio. The minimum figure which gave a good separation was four to one. The tests with various specific gravity distributions of the feed revealed that the degree of washing difficulty had no detrimental effect on the sharpness of separation given by the cyclone. These results illustrated the remarkable ability of the cyclone to cope with changes in feed rate and feed quality.

At present, a study of various schemes for expressing "cleaning efficiency" is being made to determine the applicability of these various formulas for evaluating the performance of coal washers.

A paper entitled "Laboratory Tests of the Cleaning of Fine Coal by a D.S.M. Cyclone" based upon the above work was presented at the Annual Western Meeting of the C.I.M.M. at Calgary in October, 1951.

Physical Properties of Dense Media

A study has been completed of the physical properties of five materials—magnetite, Burmis iron ore, loess, limestone, and tailings from a zinc refinery—and of suspensions of these materials in water. The aim of the investigation was to obtain information relative to the suitability of these materials for the preparation of the medium used in dense media processes for the cleaning of coal. Physical tests conducted were density and particle size of the

materials, and specific gravity, viscosity and settling rates of the suspensions. The effects of particle size on the viscosity and settling rates of the suspensions were determined for those prepared with limestone. Varying amounts of a number of dispersants were added to suspensions of limestone in water, and of loess in water, in order to determine the effects that such dispersants would have on the viscosity and stability of the suspensions.

The investigation has revealed that the density and the particle size of the solid materials influence greatly the viscosity and stability of suspensions of the above-mentioned materials in water. A solid of high density allows for suspensions which have low viscosities over a fairly wide range of specific gravities. However, the settling rates for such suspensions are high, or in other words, the suspensions are unstable. Low density materials give suspensions in water which are more stable than those made with high density materials, but the viscosities of these suspensions are high because a greater amount of the low density solid is required to give the desired specific gravity. Fine materials in suspension are more stable than coarse materials of comparable density, but suspensions made with fine materials are more viscous than those made from coarse materials. For any material in suspension, increasing specific gravity of the suspension results in a lower settling rate, that is, in increased stability.

The addition of small amounts of certain dispersants (½ to 1 percent or less was found to result in a substantial drop in viscosity but showed little beneficial effect on stability. Ranges for each of the factors studied have been determined and the data obtained have been plotted graphically. A report on the investigation is being prepared for publication.

Balling and Briquetting of Fine Coal and Asphalt

The laboratory investigation of the balling of fine coal with asphalt was discontinued since it was found that the amount of asphalt required to make a satisfactory product was too high for such a process to be economical at this time. The results of the work were presented at the Second Biennial Coal Briquetting Conference at Superior, Wisconsin, and have been published in the Proceedings of the conference. It is considered that further information could be obtained by developing the process on a larger scale and with certain improvements indicated by the laboratory investigation, but space is not presently available in which to carry out this stage of the development.

The briquetting investigation was confined to a number of small-scale tests. However, the equipment is being maintained and is available for further studies should they be requird.

Determination of Ash Content of Coal

There is need for a rapid method of determining the ash content of samples of coal collected simultaneously at various points in a coal preparation plant. In this connection a short investigation was carried out on one coal to determine the relationship between the apparent specific gravity and the ash content of the coal. A water displacement method and a volumetric method were used for determining the gravity of the coal which was then plotted against the determined ash content of the same sample. It was found that

the results of the volumetric method were slightly better than those by the displacement method, but in neither case were they considered to be satisfactory for quality control of the products in a preparation plant processing this coal.

Moisture Retention in Relation to Wet Washing

A threefold research project has been initiated as an M.Sc. thesis problem. It consists of the following interrelated topics:

(a) determination of the amount of water that is absorbed by coal during cleaning by wet processes and of the amount of surface and interstitial water retained by the coal following cleaning by wet processes.

(b) determination of the effects that additions of water repellent materials to coal may have in reducing the amount of water that clings to the coal after it has been wet washed.

(c) determination of the minimum allowable surface moisture of coals that can be shipped and stored during the winter months without undue freezing.

Visits

Visits were made by members of the staff to a number of coal mines, stripping operations and preparation plants during the year. A member of the staff attended the Annual Meeting of the Canadian Institute of Mining and Metallurgy at Quebec City, and the Coal Research meetings of the Dominion Coal Board in Ottawa. Another member attended the Second Biennial Coal Briquetting Conference held in Superior, Wisconsin. The staff was also represented at the Western Annual Meeting of the Canadian Institute of Mining held at Calgary in October.

GEOLOGY

Geological Field Work

A reconnaissance pleistocene survey was conducted in the approximately 4,000 square miles of the Lake St. Ann map area. Road accessibility became the controlling factor for the detail of this investigation. A map was prepared showing the occurrence, distribution and topographic form of glacial deposits in the eastern half of the map area. These glacial deposits take the form of three till sheets with corresponding interglacial beds, which in some localities are exposed in section to show a definite sequence of deposition. Below the oldest till exposed in any one locality, a variable bed of gravel and sands termed the "Saskatchewan Gravels and Sands" sometimes occurs. These are river-lain deposits and are used for construction purposes in places where the economics of transportation permit. These gravels may now be most easily found in old abandoned river channels. Tracing these valleys therefore becomes important near centres of building activity. Similar gravels, lying in the path of an advancing ice-sheet, and offering an increasing drag on the sole of the glacier, are thought to have been the cause of formation of drumlin-like structures. These isolated groups of hills which are numerous throughout the area sometimes have cores of wellsorted gravels. Mapping of these glacial features together with the inter-glacial deposits of lake clays and sands has provided an answer to some of the problems of glacial history within the limited area. As future work is done

in contiguous areas, so may this knowledge of the glacial history be extended and applied to geological problems both local and regional.

Sampling and Investigation of Mineral Deposits

Clay Prospect—Rocky Mountain House, Alberta

A deposit of common blue-grey clay exists at the junction of Prairie Creek with Clearwater River. At the request of the Department of Economic Affairs a limited number of samples were taken using a two-inch sampling auger to a depth of 15 feet. The deposit is of a postglacial lake type underlain by coarse sand lenses. The samples were turned over to the Department of Economic Affairs for further assessing of their value for a possible industry.

Brick Clays—Edmonton Area

Enquiries regarding the distribution of "brick clays" in the Edmonton district have been made to the Geological Section. In co-operation with the Industrial Engineer, visits have been made to the brick manufacturing firms in the Edmonton area to become familiar with the nature of the material used locally for brick and tile. Areas favourable for test-hole drilling of clay beds suitable for quarrying were outlined to the groups interested in this project.

Lacustrine Clays—Lake St. Ann Area

Postglacial lake clays exist as widespread surface deposits in the southeast quarter of the Lake St. Ann map area. The deposits represent the final accumulations of silt and "rock flour", in a postglacial lake. Such deposits form the parent material for the soils of the area and have limited economic significance to industry at the present time.

Molding Sands—Edmonton Area

The geological section has had a request for information on the possible sources of molding sands. Casting molds in the Edmonton foundries are made from natural molding sands. These are sandy clays which were formerly obtained from small lenses in recent deposits along the North Saskatchewan River. The present increase in foundry activity has necessitated the importation of molding sands from Minnesota. Steps are being taken to find an adequate local source of supply which would meet the specifications of the industry.

Gravels—Lake St. Ann—Edmonton Area

Gravels for construction purpose in Central Alberta are worked from local accumulations on river bars. A second excellent source of gravels are the old preglacial and interglacial river channels. The working out of the details of the old drainage pattern may well lead to information regarding economic concentrations of these so-called "Saskatchewan Gravels".

A large fan-shaped deposit of the "Saskatchewan Gravels" occurs between Wabamun, Isle, and St. Ann Lakes. North of the village of Wabamun the deposit of gravel is a bed 5 to 10 feet thick lying on top of the coal beds of Edmonton formation. Similar gravel deposits are found along the old valley now occupied by Kilini Creek which follows a northeasterly course from near Wabamun. Extension of this large preglacial accumulation of gravel (known as the Huff Pit), in the old drainage now covered by lake clays, should

have a continuity north of the City of Edmonton. Between Lake St. Ann and Edmonton, groups of isolated hills which have cores of stratified "Saskatchewan Gravels" have been observed. One such hill has been observed in section along the Jasper Highway west of Darwell turn-off. Similar hills exist south of Edmonton and south of Lake Isle.

Carbonate Rocks—Front Ranges of the Rocky Mountains, Alberta

Requests have been made for information on carbonate rocks which meet definite chemical specifications. As the present available information on this subject is limited, ten days were spent in the front ranges of the mountains east of Jasper sampling the limestones and dolomites of the Devonian system. These samples are to be analysed chemically and the data correlated against new thermal dissociation information and the geological environment of the rocks.

Manganese Prospects—Blue Ridge, Alberta

Three claims were staked north of Blue Ridge, Alberta, by a local syndicate. Upon a request by the parties concerned a limited field study was made of the occurrences. Minerals containing manganese dioxide do occur as coatings on boulders but no economic concentrations of manganese minerals exist in the area shown to our party by the owners of the claims.

GASOLINE AND OIL TESTING

The Gasoline and Oil Testing Laboratory continued its investigation of petroleum and associated products during the year. An increased number of samples were received from the Department of National Defence but there was a slight decrease in the test work done for industrial concerns and for individuals. A survey was again made of the gasolines sold in the Province. The results of this survey are contained in Research Council of Alberta Mimeographed Circular No. 11, "Alberta Gasoline Survey for 1951".

Work has been commenced on two projects for the Defence Research Board. These projects are designed: (1) to obtain viscosity data at low temperatures on a series of aviation lubricating oils diluted with aviation fuel, and (2) to determine the effect of storage time on performed gum, 5-hour and 16-hour potential gum tests on aviation fuel.

Close liaison has been maintained with the Sub-committee on Petroleum Specifications of the Canadian Government Specifications Board. This body handles all petroleum specifications and testing procedures covering the products used by the Department of National Defence. A member of the Council's staff attended three meetings of the committee during the year. One meeting of the Associate Committee on Petroleum of the National Research Council, held jointly with the Specifications group, was also attended. A meeting of the A.S.T.M.-D.C.C. group held in Salt Lake City was attended by another member of the staff. This group studies problems which arise in connection with the operation of knock-testing engines.

HIGHWAY RESEARCH

It was found impossible to secure the necessary staff to put a field party to work during the summer. However, three major

slides were investigated. These were located at the north approach to the Dunvegan ferry, the north approach of the Smith bridge, and at a location involving the highway and railway close to Lundbreck in the Crowsnest Pass. Each of these constituted a major problem for the Department of Highways.

A properly qualified graduate engineer will be available for the latter part of the present financial year for full-time work. His services will be used to analyse and correlate field data which have been collected during the previous three summers in connection with field compaction studies.

INDUSTRIAL PROJECTS

The work of thee Industrial Projects section consists essentially of providing technical assistance to government and industry in the field of industrial development. This work manifests itself in a variety of ways and is outlined in the following paragraphs.

A technical information service dealing with manufacturing processes and techniques is maintained for industry and individuals. Seventy-eight such inquiries were handled during the year. The following examples are shown to illustrate the nature of the inquiries: information on composition flooring, processes of oil reclamation, manufacture of printers ink, and assistance with corrosion problems.

Interviews and meetings with persons interested in industrial development provide a continuing activity. The visitors may be interested in general activity, or in specific lines such as furniture manufacture, extraction of essential oils, use of lignin compounds in clay utilization, and discussions of strawboard manufacture. Some eighty-three such interviews took place during the year.

An important aspect of the work of the Research Council, in its assistance to industrial development, is making available knowledge of our natural resources. Inquiries were received during the year for information on Alberta deposits of the following minerals: sand for construction and foundry purposes, clays for the production of brick and pottery and light weight aggregate, bentonite for use in drilling fluids, shales for rock wool manufacture, limestones and shales for Portland cement, iron ore, sulphur and gravel. This information is usually disseminated in co-operation with the geological section of the Research Council.

Requests for information are received from provincial government departments. During the past year there were twenty-one such requests from the Industrial Development Branch of the Department of Economic Affairs and eleven from the Department of Industries and Labour.

The Industrial Engineer undertakes surveys of industrial possibilities in the province. Earlier in the year a report was written on the "Possibilities of Establishing a Tobacco Industry in Alberta". It has been shown that tobacco has been grown successfully in experimental stations in the irrigated areas of Southern Alberta; however, the Canadian manufacturers of tobacco products are located in Eastern Canada and are able to meet the present requirements of the country.

At the request of the Industrial Projects Advisory Committee a preliminary report on the possibilities of an iron and steel industry

in the province was prepared. The report was a compilation of information on raw materials, processes and markets pertaining to the industry. A subsequent meeting was held of the committee and persons associated with the iron and steel industry to obtain the viewpoints of the latter. There was not general agreement amongst the visitors as to the feasibility of establishing an iron and steel industry in Alberta at this time. However, indications show that small-scale rolling operations based on scrap steel may be practical and would help provide the incentive necessary to undertake the smelting of iron oxides. The subject is still under study and an interim report will be prepared in the near future.

With the advent of extensive discoveries of oil and natural gas in Alberta it becomes appropriate to undertake a study of possibilities in the petrochemical field. An article has been prepared dealing with the nature and extent of the industry in the Texas Gulf Coast and with a comparison of the conditions of that area with our own province. The marketing of petrochemical products is not a local but a national or international problem, and while our location is less advantageous than is that of Texas for reaching the over-all markets, the situation is not too serious and suggests large-scale developments in the future.

Visits to plants in Alberta were made from time to time in order to become better acquainted with existing industry and also to offer services of technical information. Forty-seven industries were visited.

The Industrial Engineer has made some laboratory tests on clays from the Edmonton area for bloating characteristics for use in the production of lightweight aggregate. Thirty-five samples were tested with about half of them showing favourable response. A large sample of bloating clay was sent to Ottawa for large-scale tests which confirmed the results here. Other samples have been received and await testing.

NATURAL GAS

Three problems currently under investigation are: the pyrolysis of natural gas, the partial oxidation of butane, and the National Research Council Pidgeon Process for the manufacture of carbon black.

Pyrolysis of Natural Gas

The equipment was completed and preliminary tests made in an empty, externally heated, alundum tube. These were designed more to test the equipment and particularly the collection system than to gather new data. The large variation in the composition of the natural gas available, due to the introduction of air-diluted Devon gas into the city gas mains, did not permit a systematic evaluation of the data. Yields of aromatic compounds, however, were consistent with values reported in the literature. The next phase of the project involves the auto-pyrolysis of a natural gas-oxygen mixture with the heat of reaction being supplied by combustion of part of the natural gas. Auxiliary analytical equipment is being built and arrangements are being made to bring to the laboratory dry Kinsella gas of consistent composition from the Northwestern Utilities Pumping Station near the city limits.

Partial Oxidation of Butane

During the year the equipment was completed and one set of tests were carried out. In these preliminary tests commercial operating conditions were approximated although no catalyst was used. Yields of organic compounds obtained were of the expected order of magnitude. The analysis of the products presents a most serious problem and the analytical techniques must be further refined before reaction rates and yield data can be correlated.

The National Research Council Pidgeon Process for the Manufacture of Carbon Black

The Pidgeon Process developed some years ago by the National Research Laboratories on a test-tube scale indicated high yields of good quality carbon black. The Research Council of Alberta project was designed to obtain further operating and yield data, using pilot-plant equipment and commercial-size refractory tubes, in order to test the commercial possibilities of the process. It has been found that the refractory tubes recommended by Dr. Pidgeon, but in commercial size, are unable to withstand the severe temperature conditions of the process. A number of tubes of various dimensions and thicknesses were tested but none successfully withstood the conditions. The future of the project is entirely contingent upon the finding of satisfactory commercial refractory tubes or some suitable substitute.

Other Activities

Close contact has been maintained with scientific, industrial and economic advances in the field of petrochemicals. A paper concerning the use of natural gas as a chemical raw material was read to the Petroleum and Natural Gas Division of the Canadian Institute of Mining and Metallurgy, at its Annual Western meeting. Two comprehensive technical articles, "Natural Gas as a Raw Material" and "Carbon Black from Natural Gas", are almost ready for publication. In addition, two Master of Science theses were submitted to the University of Alberta in connection with the Council's work on natural gas.

SOILS

Soil surveys were continued as a co-operative undertaking between the Dominion Experimental Farm Services, the Research Council of Alberta and the Department of Soils of the University of Alberta. Accordingly, the following is a summary of all investigations undertaken in 1951.

Irrigation Soil Surveys

Bow River Project (Dominion, assisted by Research Council)

Survey work was started on this project in early May. The Hays development, which is roughly the area from the Scope east to the Bow River, was completed. Approximately 71,000 acres were surveyed in this area. This, together with the 26,000 acres surveyed in 1946, completed the Hays area survey. Much of it is Chin loam and is very good irrigation soil. Development is progressing on this project and it is expected that some irrigating will be done next year. The Research Council staff assisted with this survey until the end of June.

The western section of the project (north and south from Travers) was covered by a reconnaissance survey (portions by semi-detailed reconnaissance). This was primarily for the purpose of allocating the irrigable areas and finding the amount of arable irrigable land within the project. P.F.R.S. had requested this to assist in determining canal and storage requirements. In all, about 250,000 acres were surveyed in the western section. Most of the soil is Chin and shallow Chin loam and is fairly good irrigation soil.

William Pearce Project (Dominion, assisted by Research Council)

The survey started in 1950 was continued all summer on this project. The Research Council staff assisted until the end of June. About 320,000 acres were mapped by detailed reconnaissance survey in 1951 and slightly over 100,000 acres the previous year. To date an area roughly bounded by Coronation, Consort and Youngstown is completed. This soil is over 50% Hemarkua heavy loam (brown solodized solonetzic hardpan soil).

Aetna Project (Dominion)

Three days were spent on this project mapping the topography. This had not been done in the original survey in 1942.

Reconnaissance Soil Surveys

Rocky Mountain House Sheet (Dominion)

Due to delay from wet weather, as well as very wet conditions in the area, only a little over a week of surveying was done in the area. The total area covered was less than 100,000 acres and there is considerable surveying left to do next year.

Sturgeon Lake Sheet (Research Council)

Survey work on this project was resumed early in July and continued until late in September. Approximately 20 townships (about 460,000 acres) were surveyed mainly in the vicinity of Sturgeon Heights. The soil is primarily grey wooded on the uplands and grey black transitional or dark meadow (gleisolic) in the valleys. Most of this land had a medium-heavy tree cover.

Checking of the High Prairie and McLennan sheets preparatory to publication was completed early in October.

Edmonton Sheet

A start has been made on a re-survey of the Edmonton sheet by members of the Department of Soils. Also, at the request of the Edmonton District Town Planning Commission, a preliminary survey was completed by the Dominion and Research Council surveyors of an area surrounding the City of Edmonton designated as the Green Belt. This survey, of course, represents a small portion of the Edmonton sheet.

Other Activities

A soil survey inspection trip covering especially the grey wooded soil areas of the Peace River District and other parts of Alberta was made in late August and early September by representatives of the Alberta Soil Survey (Dominion, Research Council and University) in company with the Chief of the U.S. Soil Survey and the Head of the Department of Soils, University of Saskatchewan.

The senior Research Council surveyor made a field inspection trip with the Superintendent and Assistant Superintendent of the

Beaverlodge Station to acquaint them with the soils and possible agricultural problems of the Blueberry, Northmark, Peoria, Bad Heart and Teepee Creek areas.

Meetings of the Alberta Land Clearing Board were attended by the senior Research Council surveyor at periodic intervals throughout the summer. The area proposed for clearing in the vicinity of Valleyview was rejected by the arbitrator, and this necessitated consideration of other areas.

Six monoliths and some 100 samples of soil representing profiles typical of the area surveyed in the vicinity of Sturgeon Heights were obtained for exhibition and analysis.

Reports

(1) "Public Lands Open for Settlement in the Peace River District, Alberta." This report was prepared by the senior Research Council surveyor and the Director of Lands of the Department of Lands and Forests and has been distributed.

(2) "Soil Survey of Red Deer Sheet." Report No. 16 of the Alberta Soil Survey. This report was received from the printers in August and it will be distributed when the soil maps are obtained from Ottawa.

BIOLOGICAL CYCLES

The ten-year cycle has probably reached its peak, at least in some areas, since a drop in local population is reported this year, while rabbits, within the last month, are crashing in one district—Athabasca. Increases are, however, still being reported elsewhere (see below). This year's program has proceeded with an intensified attempt to contact observers throughout the Province, to keep a small population of rabbits under controlled conditions and to run a series of food tests on caged individuals. On account of the high rate of mortality of these animals and their continued scarcity, getting adequate numbers has been very difficult, while to keep them alive for any length of time has proved impossible.

Present Status of Species Concerned

Snowshoe Hare

Rabbits have remained at an unprecedented low for their period of peak practically everywhere. Small isolated areas have been the only sources of supply and these are difficult to locate. The persistent wet weather of the fall, coupled with the state of the roads, had led to the cancellation of numerous projected trapping attempts. The high rate of mortality of the animals in captivity has also proved a major handicap. All efforts to purchase rabbits have failed. During any normal peak it would have been simple to procure rabbits by the hundred within a 20-mile radius of Edmonton; this year attempts to get them even up to 250 miles away have proved abortive.

Jack Rabbits

This prairie hare seems still to be increasing in numbers without having attained any notable density.

Pheasant

Population apparently reaching a peak in Central Alberta. Shooting around Edmonton has been the best since 1942. The

closure of the season in the E.I.D. (Brooks) was due to a blizzard in March which exterminated at least 50% of the population.

Hungarian Partridge

While the numbers of this bird appear not to be as high as they were in 1932, the species has reached a huge peak. For the first time probably in the history of Alberta, a farmer last winter complained of being eaten out by Hungarians. As many as 500 birds could be seen on this patch at one time. About 100 Hungarians have been examined for disease and parasites since the last report. They maintain a clean sheet. The percentage of young this year remains at approximately 80%, the same as last year, showing an extremely flourishing population.

Sharp-tailed Grouse (Prairie Chicken)

Approximately 150 birds have been post-mortemed, sexed and aged, and a complete record kept of their food choices. This species is still apparently on the up-grade, though somewhat local in distribution. At Fort Vermilion, only, does it appear that they have succumbed, some 90% being infected with tapeworm. Young birds appeared to be less than 50% of the population.

Ruffed Grouse—Spruce Partridge

Both these species appear to be on the decline in some districts, though maintaining peak numbers in others. Crop contents and post-mortems have been possible on a relatively few.

Ptarmigan

These birds seem to be maintaining their numbers through most of the far North.

Questionnaire

The annual questionnaire related to wild life was continued as usual. This covers the whole of Alberta with a few picked recorders in Saskatchewan, Manitoba, and the Northwest Territories.

Rabbit Enclosures

An enclosure near Cooking Lake was stocked with some 50 rabbits during the fall and winter of 1950. The enclosure was predator-proof except for owls and hawks. Some breeding took place, but the entire population died off during the summer. Consequently, cages measuring about 10 feet by 6 feet were made available near Edmonton. Rabbits turned into these have not survived for longer than a month and most of them only for a few days. The projected experiments in these cages have thus far been abortive.

The Anzac Project

A collaborator, situated in the wilderness about 25 miles south of McMurray, continued his investigations into rabbit movements, embryo numbers and the general conditions of rabbits. At the close of the winter of 1950 the rabbit population took a noticeable drop from which it has not recovered. Directional rabbit movements on the other hand, never before suspected on a large scale, were evident. January 1951 brought with it 22 separate snow falls and left a clean sheet almost every day of the month. Numbers of tracks and their direction were thus easily determined. Full details of the movements were kept and, in addition, pathological material

was forwarded to Edmonton for examination. Notwithstanding the decrease of rabbits and the scanty records of pregnancies and embryos the data indicated a reduction of litter size.

A special investigation was made during the year to determine why rabbits along the Alaska Highway were gnawing at telephone poles. The poles belonged to the C.N.R. Communication System and the base of each pole was surface-treated with "Osmo-Creo" and sodium fluoride. A significant finding from this investigation was the surprising tolerance rabbits have for sodium fluoride. This fact was confirmed in a subsequent laboratory investigation.

ULTRA-VIOLET SOLAR RADIATION

The measurement of ultra-violet solar radiation was continued with the thorium photocell (wavelength range 0.29 to 0.367 microns) and with a zirconium photocell, although weather conditions were extremely adverse during the late summer and fall. A new type of integrating recorder is being investigated in connection with a second thorium photocell, with a view to reducing the labor involved in the evaluation of the present routine ballistic recorder charts.

LIST OF PUBLICATIONS
of
RESEARCH COUNCIL OF ALBERTA
EDMONTON, ALBERTA

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 (for 1935); pp. 43. **Price 35 cents.**
Nos. 37-43 (for 1936-1942). Not published.
No. 44 (for 1943); pp. 14. **Price 5 cents.**
No. 45 (for 1944); pp. 18. **Price 5 cents.**
No. 47 (for 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.**

REPORTS—FUELS

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 2 charts. By E. 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. **Price $1.00.**

Parts I-V—Occurrence, classification, production, special tests, general properties, preparation, utilization and combustion. **Price 50 cents.**

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.**

REPORTS—ROAD MATERIALS

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

Part I (1927)—Occurrence, pp. 74. **Price 25 cents.**
Part II (1927)—Separation, pp. 36. **(Out of print.)**
Part III (1929)—Utilization, pp. 33. **Price 25 cents.**

No. 53 (1949); THE ROLE OF VERY FINE MINERAL MATTER IN THE HOT WATER SEPARATION PROCESS AS APPLIED TO ATHABASKA BITUMINOUS SANDS, 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 ATHABASKA 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—SOIL SURVEY DIVISION

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 1 inch to 4 miles. **Price 50 cents.**

No. 31 (1935); PRELIMINARY SOIL SURVEY OF THE PEACE RIVER-HIGH PRAIRIE-STURGEON LAKE AREA, by F. A. Wyatt; with colored map. Scale 1 inch to 4 miles. **Price 50 cents.**

No. 56 (1950); SOIL SURVEY OF THE RYCROFT AND WATINO SHEETS, by Wm. Odynsky and J. D. Newton; pp. 84 and 2 maps.

REPORTS—GEOLOGICAL SURVEY

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 ATHABASKA, 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 ATHABASKA RIVERS, ALBERTA, by R. L. Rutherford; pp. 61 and 8-color map (Serial No. 7). One inch to two miles. **(Report out of print, map available.)**

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 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 75 cents.**

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 ATHABASKA AND EMBARRAS RIVERS, ALBERTA, by R. L. Rutherford; pp. 29 and 3-color map (Serial No. 11). One inch to two miles. **(Report out of print, map available.)**

No. 17 (1927); GEOLOGY ALONG BOW RIVER BETWEEN COCHRANE AND KANANASKIS, ALBERTA, by R. L. Rutherford; pp. 46 and 9-color map (Serial No. 12). Scale 1 inch to 1 mile. **Price 50 cents, or map alone 25 cents.**

No. 19 (1928); GEOLOGY OF THE AREA BETWEEN NORTH SASKATCHEWAN AND McLEOD RIVERS, ALBERTA, by R. L. Rutherford; pp. 37 and 3-color map (Serial No. 13). Scale 1 inch to 3 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 6-color map (Serial No. 14). Scale 1 inch to 4 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 1 inch to 10 miles. **(Out of print.)**

Map No. 16 (1937); GEOLOGICAL MAP OF ALBERTA (Coloured), by J. A. Allan. Scale 1 inch to 16 miles. **(Out of print.)**

Map. No. 17 (1939); GEOLOGICAL MAP OF ALBERTA (Black and white), by J. A. Allan. Scale 1 inch to 32 miles. **Price 5 cents.**

Map No. 18 (1940); COAL AREAS OF ALBERTA, by J. A. Allan. Scale 1 inch to 20 miles. **Price 25 cents.**

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

Part I—General Geology of Alberta, pp. 37, and geological map No. 17, scale 1 inch to 32 miles. **Price 50 cents.**

Part II—Rock Salt Deposit at Waterways, pp. 19. **(Out of print.)**
Part III—Geology of Alberta Soils, pp. 87. **(Out of Print.)**
Part IV—Relief Model of Alberta and its Geological Application, pp. 9. **(Out of Print.)**
Part V—Coal Areas of Alberta, pp. 36, and Map No. 18, scale 1 inch to 20 miles. **Price 75 cents.**

No. 48 (1946); GEOLOGY AND COAL OCCURRENCES OF WAPITI-CUTBANK AREA, ALBERTA, by J. A. Allan and J. L. Carr; pp. 43 and map (Serial No. 19). Scale 1 inch to 3 miles. **Price 50 cents.**

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CONTRIBUTION SERIES

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RESEARCH COUNCIL OF ALBERTA

GEOLOGICAL SURVEY

MAP 23

ELKWATER LAKE AREA

WEST OF FOURTH MERIDIAN

ALBERTA

Scale, 1 inch to 1 mile

1 0 1 2 3

Approximate magnetic declination, 20°30' East

LEGEND

CENOZOIC

TERTIARY

OLIGOCENE

Tch — CYPRESS HILLS FORMATION: *conglomerate; sandstone; clay; non-marine.*

PALEOCENE

Trs — RAVENSCRAG FORMATION: *grey sandstone; red, green and grey clays; coal; non-marine.*

MESOZOIC

CRETACEOUS

UPPER CRETACEOUS

Kfm — FRENCHMAN FORMATION: *grey, buff-weathering sandstone; non-marine.*

Kb — BATTLE FORMATION: *black, bentonitic shale; silt; volcanic ash; non-marine.*

Kwm — WHITEMUD FORMATION: *light grey, greenish-grey and brown clays; silt; sandstone; non-marine.*

Kee — EASTEND FORMATION: *grey sandstone; silt; clay; coal; non-marine*

Kbp — BEARPAW FORMATION: *dark grey shale; grey sandstone; bentonite beds; concretions; marine.*

Geological boundary (defined, approximate)

Geological locality sampled for clay 41

Well drilled for oil and abandoned

Coal mine

Road, gravelled

Road, dirt

Road along township boundary

Post Office

Interprovincial boundary

Township boundary

Forest Reserve boundary

Section line

Intermittent stream

Marsh

Contours (interval 100 feet) 4500

Height in feet above mean sea-level 4017'

Geology adapted by M.B.B. Crockford, 1948, from Map 567A, Geological Survey of Canada.

Topography from the same source.

To accompany Report 61.

SCALE: 1 Inch to 64 Miles

110°30' 110°15' 110°00'

49°45' 49°30'

TP.9,R.4 TP.9,R.3 TP.9,R.2 TP.9,R.1

TP.8,R.4 TP.8,R.3 TP.8,R.2 TP.8,R.1

TP.7,R.4 TP.7,R.3 TP.7,R.2 TP.7,R.1

TP.6,R.4 TP.6,R.3 TP.6,R.2 TP.6,R.1

Tothill Robinson Eagle Butte Elkwater Thelma Fox

Little Plume Province 54-10-4

CYPRESS HILLS FOREST RESERVE NO.I

CYPRESS HILLS

Gros Ventre Creek · Medicine Lodge · Coulee · Lodge Creek · Elkwater L. · Mackay Creek · Battle Creek · Gray Butte Creek · Thelma Creek · North Fork Creek

ALBERTA SASKATCHEWAN FOURTH MERIDIAN

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