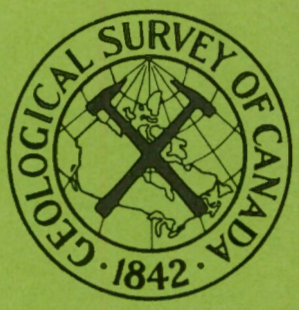

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ABSTRACTS OF PUBLICATIONS IN SCIENTIFIC JOURNALS BY OFFICERS OF THE GEOLOGICAL SURVEY OF CANADA, APRIL 1971 TO MARCH 1972

This report contains titles, and in most cases abstracts of 109 papers prepared by officers of the Geological Survey which were published in scientific journals and books between 1 April, 1971 and 31 March, 1972. The material is arranged alphabetically and in the case of multiple authorship only the name of the Survey officers is underlined.

The papers herein listed and the various reports of the Geological Survey listed in Paper 72-3, the Index of Publications 1971-72 represent most of the scientific output of the branch for fiscal year 1971-72.

Agterberg, F. P., and Kelly, A. M.

GEOMATHEMATICAL METHODS FOR USE IN PROSPECTING; Can. Mining J., v. 92, no. 5, p. 61-72, 1971.

Robertson, W. A., and Baragar, W. R. A.

THE PETROLOGY AND PALEOMAGNETISM OF THE CORONATION SILLS; Can. J. Earth Sci., v. 9, no. 2, p. 123-140, 1972.

Andrews, J. T., and Barnett, D. M.

ANALYSIS OF STRANDLINE TILT DIRECTIONS IN RELATION TO ICE CENTERS AND POSTGLACIAL CRUSTAL DEFORMATION, LAURENTIDE ICE SHEET; Geografiska Annaler, v. 54A, pt. 1, 1972.

Tilt directions on former water planes (marine and glacial lake) for 36 sites within the area of the former Laurentide Ice Sheet are projected toward the geometrical center of the ice sheet. Six zones are indicated on the basis of tilt intersections; of these, at least five have been considered as glacial dispersal centers at one time or another. The six zones are: central Hudson Bay, southeastern Hudson Bay/James Bay, central Labrador/Ungava, northwest Hudson Bay, east of Great Slave Lake, and between the St. Lawrence and James Bay. All have geographical proximity to lows on the free air gravity anomaly map, but only two are indicated on current maps of postglacial uplift and rates of recovery. Late-glacial movement of ice centers might cause the migration of the loci of postglacial uplift; there is some evidence for such events but more information is required. The areas of tilt intersections form a broad U with Hudson Bay occupying the center. The U follows the present height of land and could reflect the Laurentide ice divide at its maximum stage. In this interpretation the maximum and late-glacial ice divides are not geographically displaced.

Bamber, E. W., and Waterhouse, J. B.

CARBONIFEROUS AND PERMIAN STRATIGRAPHY AND PALEONTOLOGY, NORTHERN YUKON TERRITORY, CANADA; Bull. Can. Petrol. Geol., v. 19, no. 1, p. 29-250, 1971.

Carboniferous and Permian rocks of the northern Yukon consist of marine carbonates and shales, with minor amounts of coarse-grained terrigenous clastics. The succession ranges in age from Viséan (Meramecian) to Kazanian (Guadalupian), and is exposed in three main areas: the northern Ogilvie Mountains–Peel River area in the south; the British-Barn Mountains area in the northwest; and the northern Richardson Mountains in the northeast. Pronounced truncation beneath several regional unconformities has removed much of the upper Paleozoic succession between these three areas.

Within the thick, highly variable sequence of the northern Ogilvie Mountains–Peel River area, the following six lithologic units are recognized (base to top): Unit 1 (shale with carbonate nodules); Hart River Formation (new name, fine-grained carbonates with chert and shale); Unit 2 (carbonates and terrigenous clastics); Ettrain Formation (new name, fine- to coarse-grained carbonates); Jungle Creek Formation (new name, terrigenous clastic rocks and carbonates); and Tahkandit Formation (fine-grained carbonates and chert). Major facies changes and truncation beneath unconformities at the base of the Permian and at the base of the Mesozoic have given rise to complex distribution patterns and stratigraphic relationships for these units.

A thick upper Paleozoic sequence similar to that in northeastern Alaska is present in the British–Barn Mountains area, where the Viséan to Moscovian shales and carbonates of the Kayak Formation and Lisburne Group are separated by regional unconformities from the underlying Neruokpuk Formation and overlying undifferentiated Permian rocks. Gradational lateral and vertical changes from sandstone through shale to carbonate rocks characterize the Kayak Formation. The overlying carbonates of the Lisburne Group show a general decrease in grain size and an increase in the proportion of dolomite toward the northeast. Truncation of the entire upper Paleozoic succession of the area takes place toward the Arctic Coastal Plain beneath the sub-Triassic unconformity.

The thick upper Paleozoic succession of the northern Richardson Mountains is less complete than elsewhere in the northern Yukon, and is dominated by terrigenous clastic rocks. North of the ancestral Aklavik Arch, Carboniferous (late Bashkirian or Moscovian) carbonates occur locally between underlying Middle Devonian carbonates and overlying, widespread Permian sandstone, shale, and limestone. Near the axis of the arch, and to the south, the Permian rests on Upper Devonian and older rocks, and is truncated beneath the sub-Jurassic unconformity toward the northeastern Eagle Plain.

The configuration of carbonate and clastic facies suggests that the Carboniferous rocks of the northern Yukon accumulated under shallow-marine conditions in a continuous northwest-trending belt extending throughout the area west of the present site of the Richardson Mountains. Widespread deposition of Viséan shale and fine-grained, shallow-marine carbonates was followed by carbonate-shoal development, which began in the British–Barn Mountains area during the Late Viséan, subsequently spread southward to the northern Ogilvie Mountains–Peel River area, and became dominant during the Late Namurian (Bashkirian) to ?Gshelian (?Missourian) time. Accumulation

of terrigenous clastics and coal occurred under partly continental conditions along the northeastern margin of the area during Viséan time, and may have continued into the Moscovian (Middle Pennsylvanian). Extensive regression occurred in latest Carboniferous and earliest Permian time during uplift of the northeast-trending ancestral Aklavik Arch across the central part of the northern Yukon. Permian depositional history is largely unknown for the British–Barn Mountains area. Elsewhere in the northern Yukon, marine transgression occurred in the early Permian, and sedimentation resumed in northeast-trending facies belts, approximately at right angles to those of the Carboniferous. The ancestral Aklavik Arch controlled sedimentation and provided a source area for terrigenous clastics during Asselian and Sakmarian (Wolfcampian) time. In Artinskian to Kazanian (Leonardian to Guadalupian) time, marine transgression proceeded toward the axis of the ancestral Aklavik Arch, with the result that by Kazanian time the arch was covered by marine terrigenous clastics and carbonates. No further record of Permian sedimentation is known from the Yukon.

Biostratigraphic correlations within the upper Paleozoic of the northern Yukon are based mainly on the distribution of brachiopods and foraminifers, with supplementary data from ammonoids, spores, and corals. Brachiopods occur in 34 widespread zones and subzones ranging in age from Late Viséan (Chesteran) to Kazanian (Guadalupian). Seventeen new brachiopod genera and species are described, and typical forms from each zone are illustrated. Foraminifera associated with these brachiopods form numerous zones in the Carboniferous of the area and also occur at several levels in the Permian.

The Yukon faunal succession is divisible into 12 major biostratigraphic units, and closely resembles faunal successions found elsewhere in western and arctic North America, Spitzbergen, the Ural Mountains, and Siberia. In addition, the Yukon faunas show minor but significant similarities to the faunas of New Zealand and Australia.

Variations in brachiopod faunas indicate that the Yukon underwent paleoclimatic fluctuations in the Carboniferous and Permian similar to those that occurred in the southern hemisphere. Evidence derived from brachiopod faunas suggests that the Yukon occupied a paleogeographic position considerably closer to the Permian north geographic pole than is indicated by paleomagnetic data.

Bell, C.K.

BOUNDARY GEOLOGY, UPPER NELSON RIVER AREA, MANITOBA AND NORTHWESTERN ONTARIO; Geol. Assoc. Can., Sp. Paper 9, p. 11-39, 1971.

The Precambrian geology along the boundary between the Superior–Pikwitonei–Churchill provinces in Manitoba is summarized and correlated with the results from aeromagnetic, Bouguer gravity anomaly and geochronological surveys. The regional geophysical data was then used to extrapolate the boundary geology beneath the Central Plains and the Hudson Bay Lowland.

The Superior and Churchill provinces are partially separated by an inlier of early Precambrian, retrograded, granulite to amphibolite facies gneisses. These old rocks are included in the Pikwitonei geological province. This province is traced intermittently from the foot of Lake Winnipeg, northeast, then east, under the Hudson Bay Lowland and the flat-lying Aphebian

rocks (Nowashe and Sutton Ridges Formations) that outcrop west of James Bay. The ancient Pikwitonei province gneisses are overlapped unconformably on the southeast, and probably on the south, by 'type' Archean supracrustal rocks. Similar Pikwitonei basement rocks could even form the craton that underlies the western half of the Superior province. A younger Archean terrane then evolved on what was therefore an early Precambrian shield through preorogenic sedimentation, vulcanism and local intrusion of mafic sills, and subsequent folding, faulting and localized deposition within a conjugate series of synclinoriums. In the boundary area, synorogenic metasomatism 'granitized' large tracts of the less deformed supracrustal deposits lying between the infolded belts and formed granodiorite-tonalite anatexites. Unmetasomatized 'keels' of the synclinoriums are still preserved as narrow, linear to curved to bifurcating, east-northeast, west-northwest and east-trending "greenstone belts" that contain units of the Cross Lake, Oxford Lake and Island Lake, and Hayes River Groups. This supracrustal-granitized gneiss complex forms a 150-mile wide zone that fringes the northwest side of the Superior province. These rocks are included in the Cross Lake subprovince. Units of the Cross Lake Group lying above the unconformity are the oldest Archean rocks known on the Canadian Shield. Their preservation is hypothesized by assuming that the Kenoran event welded the Archean terrane of the Superior province and the underlying gneissic Pikwitonei province basement to form a stable crustal plate. Subsequent 'tilting' of such a shield on an east-west axis could then have uplifted the basement Archean rocks in the boundary zone and resulted in the thick Archean crust that is preserved in the 'down-tilted' south half of the Superior province.

The rocks north and northwest of the Pikwitonei province are included in the Churchill province. The early Precambrian and Archean evolution of the southeastern part of this province may have been identical to the events which produced the Superior province Archean continent, because west-trending inliers of 'type' Archean supracrustal rocks still occur there. Accordingly, when the Pikwitonei–Superior plate was up-tilted, a similar(?) Archean terrane to the north became a 'low craton' that was subsequently covered by Aphebian(?) quartzite, arkose, greywacke and intercalated volcanics. These continental deposits may represent the western extension of the Circum-Ungava geosyncline. Late Hudsonian regional anatexis 'granitized' most of these Aphebian(?) supracrustal units, although some, including the sedimentary-volcanic-ultramafic sequences in the Fox River complex, survived metasomatism but were metamorphosed.

The migmatitized paragneisses of the Thompson belt are included in the Wabowden subprovince. They are assumed to be either an autochthonous remnant that was sliced from the Archean rocks of Flin Flon subprovince, a 'horst' of Archean basement from beneath the Churchill province or an Archean allochthon that was transported by gravity, northwest, off the Pikwitonei–Superior continent into an Aphebian sea. The stratiform geometry of the nickel-bearing ultramafic members of the Thompson belt suggests a sill or flow, not a dyke origin. They were involved in tectonic remobilization and reinjection during the Hudsonian event.

Mafic and ultramafic dykes and sills of Archean(?), Aphebian and Helikian age, help to establish the province boundaries.

Archean east-northeast, west-northwest and east-striking transverse faults established the "greenstone belt" configurations and offset the Pikwitonei–Superior boundary. Late Aphebian, dextral, northwest-trending

movements rejuvenated certain Archean faults and caused further major displacements along the Superior–Pikwitonei–Churchill boundaries. Final, major shield adjustment occurred along the transverse, sinistral, Setting Lake–Assean Lake–Owl River fault systems. The entire boundary area became one stable crustal plate following Helikian injection of the Mackenzie Dykes.

The Precambrian shield in Central Manitoba is the product of crustal plate growth by stratigraphic piling, with synorogenic plate adjustment through large displacements along transverse, transcurrent and normal faults. The geology does not support Archean or Aphebian shield accretion by continental drift, in sensu stricto.

Boyle, R. W., Hornbrook, E. H. W., Allan, R. J., and Dyck, W.

HYDROGEOCHEMICAL METHODS – APPLICATION IN THE CANADIAN SHIELD; Can. Inst. Mining Met. Bull., v. 64, no. 715, p. 60-71, 1971.

Brideaux, W. W.

RECURRENT SPECIES GROUPINGS IN FOSSIL MICROPLANKTON ASSEMBLAGES; Palaeogeogr., Palaeoclimatol., Palaeoecol., v. 9, p. 101-122, 1971.

The Binomial Test is used to demonstrate the presence and distribution of recurrent species groups in fossil microplankton assemblages. These assemblages were recovered from deposits of the lower Colorado Group, Late Albian in age, from central Alberta, Canada.

The composition of the recurrent groups differs at two localities investigated in detail. In both instances, however, evidence indicates that the recurrent groups are responsive to changes in the sedimentary or environmental regime. The sequential appearance and development of the recurrent groups may be related to changes in lithology, fluctuations in the total miospore/total microplankton ratio, and proximity of ancient shoreline. Certain of the groupings were established under transgressive conditions, while others became established under more stable conditions.

Recurrent groups have value in that they allow a more refined correlation of species occurrence data with other palynological indices. They do not have stratigraphic value in themselves but may have value in the selection of local biostratigraphic markers.

Brideaux, W. W.

PALYNOLOGY OF THE LOWER COLORADO GROUP, CENTRAL ALBERTA, CANADA; I INTRODUCTORY REMARKS. GEOLOGY, AND MICROPLANKTON STUDIES; Palaeontographica Abt. B, v. 135, Lfg. 3-6, p. 53-114, 1971.

The paper discusses the biostratigraphy and taxonomy of a late Middle and late Albian dinoflagellate-acritarch assemblage from west-central, central, and south-central Alberta, Canada. The samples are drawn from subsurface sections penetrating the Peace River and Lower Shaftesbury Formations, and from the Joli Fou, Viking and Pelican Formations and the Upper Shale Unit of the Lower Colorado Group. Three assemblages and one sub-assemblage

are recognized, based mainly on this study, but including evidence from earlier reports. These are: an earlier Middle Albian Lejeunia? cretacea assemblage, a later Middle Albian Microdinium opacum assemblage, a Late Albian Spinidinium vestitum assemblage and a later Late Albian Scriniodinium eurypylum sub-assemblage.

Of sixty-four species described and illustrated in this paper, the following are new: Baltisphaeridium rallum, B. turbinatum, B. admixtum, Microdinium opacum, Gonyaulacysta globosa, G. obesa, G. auctifica, G. fragosa, Oligosphaeridium totum var. totum, O. totum var. minor, Hystrichosphaeridium cylindratum, Spinidinium vestitum and Pseudoceratium expolitum. New taxonomic treatment is accorded Lejeunia? cretacea (Pocock) comb. nov., Cleistosphaeridium multispinosum (Singh) comb. nov. and Gonyaulacysta indicosa nom. nov.

Burk, C.F., Jr.

COMPUTER-BASED GEOLOGICAL DATA SYSTEMS: AN EMERGING BASIS FOR INTERNATIONAL COMMUNICATION; Proc. Eighth World Petrol. Cong., v. 2, p. 327-335, 1971.

The utilisation of computer technology for storage and retrieval of geological data has increased greatly in the past four years, most actively in connection with petroleum well data systems and geochemistry. Important files have also been established for hydrogeology, mineral and fuel deposits, petrology, field mapping, and geophysics. Computer-based systems applied to these data are viewed in terms of four aspects: the data, encoding methods, computer processing, and display techniques. Recent developments in each are briefly summarised.

Examples of applications have been provided mainly by the petroleum industry; those cited here are related to routine retrievals, maps and cross-sections, mathematical geology, basin analysis, wireline log analysis, geochemical and geological surveys, and public dissemination of data.

Electronic storage and retrieval methods have had an impact not only in terms of applications, but, more profoundly, by forcing examination of the nature, significance, and role of data (i.e. observations and measurements) in geological activities. Use of computer-based methods has emphasised the general lack of communicable data in geology and the over-abundance of interpretation. However, improvements can be expected as a result of current efforts to develop national and international systems which could form a basis for worldwide communication of geological data.

Burk, C.F., Jr.

DEVELOPMENT OF AUTOMATED GEOLOGICALLY-BASED INVENTORIES OF MINERAL AND FUEL RESOURCES IN CANADA; Geoscience Documentation, p. 132, 1970.

This paper summarises current efforts in Canada, based at the Canadian Centre for Geoscience Data, to utilise automated data systems in the development of geologically-based inventories of mineral and fuel resources. The Canadian system is of owner-controlled linked Data Files constituting a Canada-wide network, and is not a central 'data bank'.

Flueckinger, Linda A., Dutcher, Russell R., and Cameron, Alex R.

STATISTICAL EVALUATION OF COAL COMPOSITIONAL DATA; J. Geol., v. 80, p. 237-247, 1972.

Statistical techniques were applied to petrographic and chemical data obtained on 35 samples of coal ranging from lignite to anthracite. Six petrographic variables were involved in the calculation and included contents of vitrinitic components, fusinoids, massive and granular micrinoids, and exinoids plus resinoids. Also included was the mean maximum reflectance determined on the vitrinitic entities. Chemical variables included contents of ultimate carbon, hydrogen, total sulfur, and oxygen which was found by difference. Statistical techniques involved calculation of a correlation matrix and factor analysis with factor rotation. In the former procedure, positive correlations at the 1% significance level were shown to exist between carbon and vitrinite reflectance, between hydrogen and micrinoids and exinoids, between oxygen and micrinoids and exinoids, and between micrinoids and exinoids. A factor analysis by the R mode showed that four factors appeared to be responsible for 94% of the variation. The contents of oxygen, and carbon and the reflectance values are related to factor 1 (F1), which is provisionally regarded as metamorphism after burial. The content of vitrinitic material plus the content of micrinoids and exinoids appear to be related to factor 2 (F2), which is provisionally regarded as involving the type of source vegetation and the degree of biochemical alteration in the peat swamp. Sulfur appears to be related to a third factor and the fusinoids to yet another. These are special environmental elements critical in the distribution of the two variables in question but not of special significance in connection with the other variables.

Cameron, E.M., and Baragar, W.R.A.

DISTRIBUTION OF ORE ELEMENTS IN ROCKS FOR EVALUATING ORE POTENTIAL: FREQUENCY DISTRIBUTION OF COPPER IN THE COPPERMINE RIVER GROUP AND YELLOWKNIFE GROUP VOLCANIC ROCKS, N.W.T., CANADA; Can. Inst. Mining Met., Sp. Vol. 11, 1971.

Several investigators have shown that the frequency distribution by size of genetically related economic ore deposits within a given area or rock unit obeys probability laws, with many of these distributions approximating log-normal distribution functions. The lower bounds of these distributions appear to be always 'artificially' limited by economic considerations such as size and grade. The sampled deposits are therefore probably only the extreme right tail of a more general probability distribution for the ore minerals in the given unit, with the lower, much more frequent, components of the distribution being represented by segregations of ore material ranging in size from 'showings' to single grains.

Unfortunately, the function best describing an empirical distribution cannot be relied upon to remain constant across the entire range of size classes. It is therefore not possible to predict, by conventional probabilistic methods, the frequency and size of ore deposits from data on the more frequent size classes of the given unit. It does, however, behoove the geochemist to make the best use of the latter data, which may readily be obtained by chemical analysis of samples from surface exposures, to estimate the ore potential of

a rock unit or area. Such data are likely to become among the more useful inputs to mathematical methods of decision making in mineral exploration.

The distribution of copper within two groups of volcanic rock, one containing ore deposits, the other apparently barren, have been compared. Both groups are of dominantly basaltic composition, are of Precambrian age and outcrop over wide areas of the Northwest Territories. The Coppermine River Group contains abundant showings of copper and at least one economic deposit of this metal. The copper ore is believed to have been derived primarily by segregation of copper sulphides from the parent Coppermine River magma. The second group is the Yellowknife Group which, within the area sampled, contains no known copper deposits. HNO_3-soluble copper has been measured on 715 samples of the Coppermine River Group and 195 samples of the Yellowknife Group. The Coppermine River data show the type of distribution which is believed to be the likely accompaniment of ore deposits – a right-skewed distribution which is continuous into the range of thousands of ppm copper. The Yellowknife data are not right-skewed, and no sample exceeds 273 ppm copper.

Cameron, E.M., and Hobbs, D.

COMPUTERIZED METHODS FOR INTERPRETING RECONNAISSANCE GEOCHEMICAL SURVEYS; Can. Inst. Mining Met., Sp. Vol. 11, 1971.

The principal purpose of computerized methods for interpreting reconnaissance data is to extract and lucidly display the greatest amount of information relating specifically to potential ore deposits. An important by-product is the considerable reduction in the labour of manual collation, interpretation and plotting.

The procedures used for interpretation aim at the separation of the chemical "signal" caused by ore deposits from other signals and from random noise. At present, perhaps the most generally useful technique is to contour by computer the residuals from a low-order polynomial trend surface. The trend surface removes the gradual variation due to regional lithologic change, climate, vegetation and topography; the moving average approach utilized in computer contouring reduces the effect of random noise and reveals zones of consistent local variation. The choice of the most appropriate form of trend surface and of the parameters of the contouring method remain highly subjective, and thus the comparison of the effectiveness of other surface-fitting methods is urgently required. The many methods developed for communications theory and other sciences offer considerable scope for the geochemist. Because, in most reconnaissance surveys, material is sampled at intervals along linear drainage features, such techniques as Markov schemes are of potential application. Apart from these sophisticated techniques, simpler methods may often be quite effective in separating the signals. For instance, if the rocks of an area can be subdivided into a few, relatively homogeneous lithologic types, the element concentrations in each sample may be normalized using the mean and variance of all samples overlying that particular rock type.

The above methods utilize the relationship between the concentration of one element in a sample to the concentrations of the same element in surrounding samples to differentiate the signal of interest from other sources of variation. A different approach to separating the signals is to use multi-

variate techniques which employ the relationship between the different elements contained in the samples. The methods that have sparked most interest are component and factor analysis, although other methods may prove to be more effective. Each factor that is extracted hopefully represents the variation that is due to but one geological or geochemical process, rather than the sum of processes that is usually represented by the concentration of an element. Scores may be computed measuring the influence of every factor on each sample, and these data may be trend-surfaced, contoured and plotted in the same fashion as the original element data. It may often be useful to apply component or factor analysis to the residuals from a trend surface, as the trend surface may be effective in removing some "factors", thus simplifying the task of the multivariate procedures.

Notwithstanding the above, factor analysis may often be inappropriate for the interpretation of reconnaissance data. The methods are designed to extract a set of factors operating within a single population. If the area studied is heterogeneous in terms of its geology and assemblage of mineral deposits, there may be a very large number of different factors or processes acting upon the same variables, which is quite beyond the ability of factor analysis to resolve. The interpretation given by factoring these conditions may be quite misleading. Such effects may be tested by subdividing the data by subarea and determining whether the factor matrices are reasonably constant between the subareas. The second impediment to utilizing factor analysis for reconnaissance surveys is that six to eight elements may be too few to significantly resolve the factor structure, which remains constant, irrespective of the number of elements that may be determined.

It is perhaps not generally appreciated that the introduction of such powerful statistical methods may require changes in other aspects of the reconnaissance survey. For instance, to get the best results from trend-surface and contouring methods demands a reasonably even distribution of samples over the area and more attention to optimizing the sampling interval in terms of both economics and the size of the expected anomalies. In general, the utility of factor analysis increases with the number of variables factored. More attention should be given to determining major elements simultaneously with the trace metals (as may be done with a direct-reading optical spectrometer). Factoring of such data would considerably reduce the effect of variation of the trace indicator metals that is due to varying quantities of major minerals in the sediment.

Cameron, E. M., Siddeley, G., and Durham, C. C.

DISTRIBUTION OF ORE ELEMENTS IN ROCKS FOR EVALUATING ORE POTENTIAL: NICKEL, COPPER, COBALT AND SULPHUR IN ULTRAMAFIC ROCKS OF THE CANADIAN SHIELD; Can. Inst. Mining Met., Sp. Vol. 11, 1971.

For large deposits of nickel-copper sulphides to separate from an ultrabasic magma, the sulphur content of that magma must be relatively high at an early stage in its crystallization history. If the sulphur content is high, the solubility products of metal sulphides will be exceeded and sulphide liquid or crystals will separate and have the opportunity to coalesce before they can be trapped and diluted by crystallizing silicate minerals. The purpose of this study was to discover whether there was indeed enrichment of sulphur or sul-

phides of copper, nickel and cobalt in ultramafic rocks associated with copper-nickel deposits and, if this were so, to determine the best combination of chemical variables for predicting the ore potential of an ultramafic body.

A total of 1,079 samples of ultramafic rock were collected from 61 widely scattered localities across the Canadian Shield and the Eastern Townships of Quebec – 372 of these samples come from ultramafic bodies associated with moderate to large deposits of nickel-copper sulphides; 91 are from bodies associated with small deposits or significant showings of sulphides; and the remaining 616 samples come from barren ultramafics or those containing only minor quantities of sulphides. Copper, nickel and cobalt, present as sulphides, were determined from these samples by atomic absorption spectrometry, following leaching with a mixture of ascorbic acid and hydrogen peroxide. Sulphur was determined by a combustion method.

Sulphur and leachable copper, nickel and, to a lesser extent, cobalt are considerably enriched in the ore group of ultramafic rocks compared to the barren samples. Discriminant equations have been derived to best distinguish between the ore and the barren groups. Copper and sulphur contribute the most information to these discriminant equations, with nickel less and the contribution of cobalt negligible. Differences in the ratios of the above elements between the different groups of ultramafic rocks and between these rocks and the associated mineral deposits contribute to an understanding of the processes of chemical adjustment between sulphides and silicates that take place after crystallization of the primary minerals.

Cumming, L. M.

ORDOVICIAN STRATA OF THE HUDSON BAY LOWLANDS IN NORTHERN MANITOBA; Geol. Assoc. Can.; Sp. Paper 9, p. 189-197, 1971.

Ordovician strata underlie approximately 125,000 square miles of the Hudson Bay Lowlands and comprise three main rock stratigraphic units (in ascending succession); Bad Cache Rapids Group, Churchill River Group and Red Head Rapids Formation. In northern Manitoba, Ordovician strata are best exposed on the Gods, Nelson, Churchill, South Knife and North Knife Rivers and on Herriot Creek. The Ordovician strata of Hudson Bay Lowlands are primarily carbonate rocks that were deposited in a variety of environmental settings within a northern, predominately arid, climatic zone.

A peneplaned surface at the base of Upper Ordovician strata in northern Manitoba is exposed on the North Knife, Churchill and Nelson Rivers. Best exposures are on the Churchill River, below Portage Chute, where the slope of the peneplain toward the centre of Hudson Bay is approximately equal to the river gradient.

Currie, K. L.

ORIGIN OF IGNEOUS ROCKS ASSOCIATED WITH SHOCK METAMORPHISM AS SUGGESTED BY GEOCHEMICAL INVESTIGATIONS OF CANADIAN CRATERS; J. Geophys. Res., v. 76, no. 23, 1971.

Chemical analyses of igneous and country rocks from Canadian craters show that the igneous rocks are consistently richer in potassium, magnesium, and heavy metals, and poorer in sodium and silicon than their associated country rocks. Geochemical balance calculations suggest that 20-80 per cent of the igneous rocks are composed of material not found in the country rocks, commonly a potassic basic to ultrabasic rock, such as those exposed in the craters Brent, Manicouagan, and Clearwater. Low-grade fenitization occurs at Brent. These data are not compatible with origin of the igneous rocks by either shock melting, or impact-induced volcanism. The data suggest explosive alkaline volcanism for the origin of at least some of the rocks.

Ferguson, John, and Currie, K. L.

EVIDENCE OF LIQUID IMMISCIBILITY IN ALKALINE ULTRABASIC DIKES AT CALLANDER BAY, ONTARIO; J. Petrol., v. 12, pt. 3, p. 561-585, 1971.

Monchiquitic and camptonitic dikes radiating from an alkaline carbonatite intrusion display sharply bounded, ellipsoidal, coarse-grained segregations of predominantly leucocratic minerals, identical in both composition and zoning to minerals in the matrix. These ocelli are not found in chilled margins, but elsewhere occur in layers or segregations within the intrusives. Similar phenomena are seen in rocks of similar composition, both plutonic and volcanic, the world over. Field relations, detailed mineralogy, and macro- and micro-chemical studies strongly suggest that they result from liquid immiscibility in ultrabasic alkaline magma.

Hydrothermal melting experiments show that olivine-bearing dikes with carbonate-rich ocelli melt to a homogeneous silicate liquid, and an immiscible CO_2-rich fluid phase. Kaersutite-bearing lamprophyre with felsic ocelli yields a homogeneous silicate liquid on first melting, but on further heating this liquid dissociates into two immiscible portions. The data strongly suggest that an initial carbonated nephelinitic magma could give rise by successive immiscibility to carbonatite, melteigite, and nepheline syenite liquids.

Currie, K. L., and Ferguson, John

A STUDY OF FENITIZATION AROUND THE ALKALINE CARBONATITE COMPLEX AT CALLANDER BAY, ONTARIO, CANADA; Can. J. Earth Sci., v. 8, p. 481-497, 1971.

Fenitization in granitoid rocks is first noticeable in the form of hematite veinlets, accompanied by increased ordering of potash feldspar. With increasing fenitization, plagioclase is converted to albite plus calcite, and K-feldspar progressively converted toward maximum microcline. Acmitic pyroxenes become increasingly abundant. The chemical changes producing these effects consist of the substitution of sodium plus another cafemic

ion for silicon in such a way as to maintain charge balance. The fenitizing fluid was essentially an NaCl brine, roughly 1 molal in alkali chlorides, and 0.01 molal total acidity. The content of iron, calcium, and magnesium was high. The oxygen fugacity was near 10^{-17} bars (hematite-magnetite), and the sulfur fugacity near 10^{-12} bars. Fenitization may have occurred at temperatures as high as 700°, but the main fenitization took place at temperatures slightly above 500° and fenitization ceased at about 450°. Pressures were low, probably less than 500 bars. The source of the fenitizing solutions was carbonatite, which in turn was derived from nephelinitic magma.

Currie, K. L.

THE COMPOSITION OF ANOMALOUS PLAGIOCLASE GLASS AND COEXISTING PLAGIOCLASE FROM MISTASTIN LAKE, LABRADOR, CANADA; Mineral. Mag., v. 38, p. 511-517, 1971.

Anorthosite country rocks near the fissure vents of an andesitic resurgent caldera contain coexisting crystalline plagioclase, pseudomorphous plagioclase glass, and anomalously dense, massive plagioclase glass. Glass pseudomorphous after labradorite (An_{53}) has the composition of oligoclase (An_{17}). Large masses of dense plagioclase glass have compositions near An_{53}, but relict crystalline plagioclase within them has compositions near An_{80}. Devitrification products of this glass have potassium-rich compositions. These compositions are compatible with partial thermal melting in a high-temperature, moderate-pressure pulse. Such a pulse might be associated with a confined chemical explosion.

Currie, K. L.

A STUDY OF POTASH FENITIZATION AROUND THE BRENT CRATER, ONTARIO - A PALEOZOIC ALKALINE COMPLEX; Can. J. Earth Sci., v. 8, no. 5, p. 481-497, 1971.

Fractured and brecciated granitoid gneisses around and within the Brent Crater display progressive chemical and mineralogical changes due to metasomatism, culminating in potassic, silica-undersaturated metasomatic rocks. In the metasomatized rocks, potash feldspar increases in amount and degree of triclinicity with increasing metasomatism, while quartz and plagioclase decline in amount. Calcite of carbonatitic isotopic character is found in some of the breccia matrices. Alkaline ultrabasic dikes, identical in chemistry, petrography, and radiometric age to those of the Nipissing alkaline petrographic province, cut the breccia. Potassic trachyte, which appears to form dikes and lenses within the crater, may be the result of anatexis of potassic metasomatites. The geometric form, petrography, and chemical trends of the metasomatized rocks are virtually identical to those of the fenite aureole of the Callander Bay alkaline carbonatite complex, 42 miles (67.6 km) to the west, suggesting that they result from a fenitization process in which potassium rather than sodium is enriched.

Currie, K. L.

THE REACTION. 3 CORDIERITE = 2 GARNET + 4 SILLIMANITE + 5 QUARTZ AS A GEOLOGICAL THERMOMETER IN THE OPINICON LAKE REGION, ONTARIO; Contr. Mineral. Petrol., v. 33, p. 215-226, 1971.

In equilibrated metamorphic rocks containing coexisting garnet, cordierite, quartz and sillimanite, the exchange of iron and magnesium between cordierite and garnet offers a highly favourable geological thermometer and barometer, because this exchange reaction is insensitive to pressure. Thermodynamic analysis shows that this thermometer may be calibrated from knowledge of the breakdown reactions for iron and magnesian cordierite end members to garnet. The thermometer was experimentally calibrated using cordierites of intermediate composition. When applied to rocks showing petrographic evidence of equilibrium, and chemical evidence of reaction between garnet and cordierite, the thermometer yielded temperatures of 600-750°C, and pressures of 5.7-6.7 kilobars. Similar conditions are indicated by other literature data on cordierite-garnet gneisses, and are believed to represent hornblende granulite grade of metamorphism.

Ferguson, John, and Currie, K. L.

SILICATE IMMISCIBILITY IN THE ANCIENT "BASALTS" OF THE BARBERTON MOUNTAIN LAND, TRANSVAAL; Nature Phys. Sci., v. 235, no. 57, p. 86-89, 1972.

The presence of spherical bodies in basaltic rocks strongly suggests that they are globules produced by liquid immiscibility of silicate fractions. Chemical analyses and experimental work support the concept that some of the rock types found in the Barberton Mountain Land, Transvaal, owe their origin to an unmixing of magmas.

Darnley, A. G., and Grasty, R. L.

MAPPING FROM THE AIR BY GAMMA-RAY SPECTROMETRY; Can. Inst. Mining Met., Sp. Vol. 11, 1971.

Since 1967, the Geological Survey of Canada, in conjunction with Atomic Energy of Canada Ltd., has been developing a high-sensitivity airborne gamma-ray spectrometer system for the purpose of measuring surface concentrations of K, eU and eTh. During the initial stages of the program, which have been described in earlier publications, problems of optimum spectrometer design, calibration and data correction were investigated. At the same time, ground investigations were undertaken to compare the K, eU and eTh content of various rock types and overburden. One of the most important findings of this research was that, in the Shield areas examined, there is a close similarity between the radiometric composition of rock and its associated overburden.

In 1969, the first extended trials of the complete spectrometer system took place, with a detailed survey of approximately 400 square miles in the Bancroft area of Ontario. Flight lines flown at 400 ft above surface

were spaced at 1/4-mile intervals and radiometric data were accumulated, with read-out onto magnetic tape at approximately 500-ft intervals along the flight line. In this way, approximately 75 per cent of the total surface of the area has been radiometrically sampled. The data on the magnetic tape have been corrected to allow for variable atmospheric radioactivity, variations in terrain clearance, and Compton scattering contributions in the spectrometer's lower energy channels. Corrected profiles have been computer-drawn along each flight line and a variety of computer-drawn geochemical maps have been made over the area covered, based on a contouring program devised by Holroyd and Bhattacharyya. These show good correlation with the known surface geology, and principal rock types in the area can be distinguished. Information is also provided about the northeast-trending zone of uranium and thorium enrichment which crosses the area, and a subdivision of granitic types can be made. The relative abundances of the various radioelements are shown to be a sensitive indicator of unusual concentrations, and these variables are particularly significant in using this type of data for mineral exploration purposes.

Davies, G. R.

A PERMIAN HYDROZOAN MOUND, YUKON TERRITORY; Can. J. Earth Sci., v. 8, p. 973-988, 1971.

A carbonate mound built by the hydrozoan Palaeoaplysina has been found in a poorly-exposed sequence of Lower Permian rocks in the northern Richardson Mountains of the Yukon Territory. Similar hydrozoan mounds have been described from Russia and northwestern United States. The Yukon mound is 12 ft (3.7 m) thick and at least 70 ft (21 m) long. It is underlain by marine siltstones and sandstones, and probably shale. The main mound rock is composed of curved hydrozoan plates enclosed in a bioclastic wackestone matrix, and is overlain successively by tubular-foram packstone and oolitic grainstone. Palaeoaplysina is characterized by a plate-like, laterally-expanding growth form, an internal canal system, a cellular calcareous skeleton, and 'mamelons' on the upper surface of well-preserved plates; 'mamelons' are the principal criterion for placing Palaeoaplysina in the Class Hydrozoa of the coelenterates.

The Yukon mound is part of a thick sequence of Lower Permian terrigenous clastic and carbonate rocks deposited on the northern shelf of the ancestral Aklavik Arch. The repetition of similar rock types in the sequence indicates cyclicity, a thesis supported by similarities between the Yukon mound sequence and the Virgilian mound cycles in New Mexico.

Lower Permian hydrozoan mounds and associated facies in the Prerurals of Russia are known oil producers. The possibility exists that hydrozoan mounds, perhaps in multiple cyclic build-ups, may occur in upper Paleozoic rocks in the subsurface of the Yukon Territory. With suitable porosity development and source rocks, these predicted subsurface mounds could become hydrocarbon reservoirs and thus targets for oil exploration.

Davies, G.R., and Nassichuk, W.W.

UPPER PALEOZOIC EVAPORITES IN SVERDRUP BASIN, ARCTIC CANADA; Am. Assoc. Petrol. Geol. Bull., v. 56, no. 3, p. 612, 1971.

Carboniferous and Permian evaporites and associated rocks in Arctic regions are of current interest in terms of global paleogeography and petroleum exploration. In the Canadian Arctic Archipelago, 3 upper Paleozoic evaporite formations are present in the Sverdrup basin, a regional depression overlying the Franklinian geosyncline and containing 40,000 ft (13,000 m) of lower Carboniferous to Eocene sediments. Two of these formations are: the Otto Fiord Formation (upper Carboniferous) in the axial region of the basin, and the Mt. Bayley Formation (Lower Permian), which is closer to the eastern basin margin. A third, unnamed evaporite unit of Moscovian or younger age is present along the north coast of Ellesmere Island.

The Otto Fiord Formation consists of over 1,300 ft (430 m) of interbedded anhydrite (75% by thickness) and limestone (25%) at the type section, with interbedded sandstones in other sections. The formation overlies sandstones and conglomerates of the Borup Fiord Formation (Namurian?), grades laterally into carbonates of the Nansen Formation, and is overlain by carbonates or siltstones of the Hare Fiord Formation (Moscovian at base). The Otto Fiord evaporites extend for at least 400 mi (650 km) in a broad, northeast-trending belt characterized in the south by numerous large piercement structures. Namurian and Bashkirian ammonoids discovered in these diapirs now have been found at several levels in the Otto Fiord type section.

Apart from a few cubic crystal clasts, there are no positive indications of halite in surface exposures of the Otto Fiord Formation; breccia zones in anhydrite and limestone are not extensive. The Otto Fiord anhydrite beds vary in fabric from indistinctly bedded nodular mosaics, to fabrics apparently pseudomorphic after coarsely crystalline gypsum. Fabrics and bedding of the anhydrite, the biota of limestone interbeds, and the associated lithofacies indicate a marine subaqueous mechanism of deposition for these evaporites.

Davies, G.R., and Ludlam, S.D.

A BASINAL MODEL FOR MIDDLE DEVONIAN "LAMINITES," ELK POINT BASIN OF WESTERN CANADA; Abstr. Program, Geol. Soc. Am., v. 3, no. 7, p. 538, 1971.

Laminated calcitic, dolomitic and anhydritic rocks (laminites) of the Middle Devonian Keg River Formation of Alberta and the equivalent Winnipegosis Formation of Saskatchewan have been interpreted variously as deep-water sediments and as intertidal-supratidal deposits. Interest in laminite genesis has been stimulated recently by application of the Persian Gulf tidal-flat model to explain formation of laminae by algal mat growth, with subsequent anhydrite emplacement during supratidal diagenesis.

The authors propose a density-stratified basinal model for laminite deposition based on a study of modern laminated sediments in lakes of the northeastern United States, supplemented by data from the Dead Sea and other saline basins. In this model, carbonate and sulphate laminae form as precipitates controlled by seasonal or longer-term climatic processes, while dark-

coloured 'organic' laminae form by sedimentary accumulation of organic detritus during periods of non-precipitation. Graded carbonate beds containing laminar clasts and interstratified with the laminites may be compared with graded turbidity-current beds (turbidites) found in modern lakes. Lack of bioturbation and absence of fossils of benthonic organisms in the laminites are attributed to the influence of a deoxygenated environment below a chemocline. Support for the model is found in continuity of individual laminae over distances in excess of 15 mi (24 km), similarities in sedimentary structures between Devonian and Recent laminites and graded beds, and in facies relationships with associated Devonian sediments. Correct genetic interpretation is critical for reconstruction of Devonian paleogeography and interpretation of diagenetic processes.

Dean, W.T.

THE LOWER PALEOZOIC STRATIGRAPHY AND FAUNAS OF THE TAURUS MOUNTAINS NEAR BEYSEHIR, TURKEY. II. THE TRILOBITES OF THE SEYDISEHIR FORMATION (ORDOVICIAN); Brit. Mus. Nat. Hist. Bull., v. 20, no. 1, 24 p. 1971.

Dean, W.T.

THE TRILOBITES OF THE CHAIR OF KILDARE LIMESTONE (UPPER ORDOVICIAN) OF EASTERN ICELAND; Plaeontogr. Soc. Monogr., v. 125, no. 531, 1971.

Douglas, J.A.V., and Plant, A.G.

TRANQUILLITYITE: A NEW SILICATE MINERAL FROM APOLLO 11 AND APOLLO 12 BASALTIC ROCKS; Proc. Second Lunar Sci. Conf., v. 1, p. 39-45, 1971.

Tranquillityite ($Fe_8^{2+}(Zr + Y)_2Ti_3Si_3O_{24}$) is a new silicate mineral which also contains minor amounts of Ca, Al, Mn, Cr, Nb, REE, Hf, and 50 to 93 ppm U and occurs in association with late-stage interstitial phases in both Apollo 11 and Apollo 12 basaltic rocks. The preliminary structure data indicate a hexagonal lattice $a_o = 11.69 \pm 0.05$ Å, $c_o = 22.25 \pm 0.10$ Å with a resultant volume per M_2O_3 formula unit of 54.9 ± 0.8 Å^3 and a theoretical density of 4.7 ± 0.1 g/cm^3. In transmitted light the mineral is semiopaque with a dark foxy-red color and is nonpleochroic. It is gray in reflected light with $R = 12.9 \pm 0.2$ at 546 nm in air so that the average refractive index values lie between 2.11 and 2.13. It is isotropic or very weakly anisotropic.

Dence, M.R., Douglas, J.A.V., Plant, A.G., and Traill, R.J.

MINERALOGY AND PETROLOGY OF SOME APOLLO 12 SAMPLES; Proc. Second Lunar Sci. Conf., v. 1, p. 285-299, 1971.

Five crystalline rocks, one breccia, and a sample of coarse (1-2 mm) fines have been examined. Of the rocks, samples 12046, 5 and 12056, 4 are subophitic microgabbros which differ from Apollo 11 rocks of similar texture mainly in that strongly zoned clinopyroxenes have pigeonite cores. Rock 12057, 35 is an equigranular olivine-pyroxene cumulate with

38% modal olivine. Rocks 12021, 2 and 12053, 85 are porphyritic variolitic basalts. In 12021, 2 phenocrystic pyroxenes have uniform cores of pigeonite ($Wo_{11}En_{61}Fs_{28}$), probably grown at some depth, mantled by oscillatory zoned calcic pyroxene. Similar zoning in plagioclase indicates that in the later stages of crystallization the magma underwent periodic changes in composition. The finer-grained porphyritic variolitic basalt 12053, 85 and some rock fragments in coarse fines 12070, 148 show a similar though less complex zoning of pyroxene phenocrysts. A survey of rock fragments from 12070 indicates that varieties similar to 12053 and 12056 are the principal rock types underlying the Apollo 12 site. Light colored rock and breccia fragments plus glasses, making up 18% of 12070, are considered to have distant provenance, as do many inclusions in breccia 12073, 12. They include noritic fragments with brown glass matrix rich in K_2O and P_2O_5, mauve-brown impact glasses also with high K_2O and P_2O_5, pale green glasses in which Na_2O is enriched relative to K_2O, colorless glasses of anorthositic gabbro composition. Each group requires a distinct though possibly related source.

Dyck, Willy

A SIMPLE DIFFUSION CELL FOR THE DETERMINATION OF ABSOLUTE DIFFUSION CONSTANTS USING RADIOACTIVE TRACERS; Can. J. Chem., v. 49, p. 1575-1578, 1971.

Using microscope slides for the diffusion grating, a glass diffusion cell was constructed which permitted the determination of absolute diffusion constants of γ-ray emitting elements in aqueous solutions.

The cell was tested at 25°C with ^{110}Ag as tracer and gave a bulk-diffusion coefficient of 1.64×10^{-5} cm^2/s and a self-diffusion coefficient of 1.48×10^{-5} cm^2/s using 0.01 M $AgNO_3$.

The hydrogen ion concentration had no detectable effect on the diffusion coefficient of $AgNO_3$ in the pH range -0.48 to 7.5. The presence of Na or Fe(III) ions, or sucrose molecules at moderate concentrations (>0.1 M) resulted in a marked decrease in the diffusion coefficient.

Eckstrand, O.R.

THE NICKEL POTENTIAL OF SERPENTINIZED ULTRAMAFIC ROCKS; Can. Mining J., v. 92, no. 4, p. 40-42, 1971.

Eisbacher, G.H.

NATURAL SLOPE FAILURE, NORTHEASTERN SKEENA MOUNTAINS; Can. Geotech. J., v. 3, p. 384-390, 1971.

Twenty-five rockslides in sedimentary strata of the Skeena Mountains in north-central British Columbia are concentrated along a distinct belt approximately 30 km wide. Four slides belong to a "shallow" type, 21 to a "deep" slide type. Regional structural trend, deformation, and lithological heterogeneity seem to control distribution and direction of slip of these rockslides. Slopes oriented parallel to the structural trend and made up of heterogeneous conglomerate, sandstone, shale successions are more likely to fail than others.

Ermanovics, I.F.

'GRANITES', 'GRANITE GNEISS' AND TECTONIC VARIATION OF THE SUPERIOR PROVINCE IN SOUTHEASTERN MANITOBA; Geol. Assoc. Can., Sp. Paper 9, p. 77-81, 1971.

The Precambrian terrain of the Superior structural province of southeastern Manitoba, between latitudes 51 and 53 degrees north, is characterized by gneissic and massive monzonite to granodiorite bodies, constituting 80 per cent of the exposed rocks. Three domains are distinguished: metavolcanic-sedimentary rocks (domain I), an adjacent, hybridized mobile zone (domain II), and a sialic nucleus (domain III). Domains I and II constitute the total volcanic-sedimentary tectogene, originally deposited on the 'sialic' nucleus of domain III. It is implied that this three-fold division may have general application in any hypothesis extending the present distribution of greenstone belts.

Ermanovics, I.F., Helmstaedt, H., and Plant, A.G.

AN OCCURRENCE OF ARCHEAN PSEUDOTACHYLITE FROM SOUTHEASTERN MANITOBA; Can. J. Earth Sci., v. 9, no. 3, p. 257-265, 1972.

Zoned veins (glass and crushed rock) of pseudotachylite occur in an Archean mylonite near Charron Lake, Manitoba. Glass occupies the centers of some veins and fusion products penetrate symmetrically distributed, rock zones. The emplacement of the pseudotachylite postdates the formation of the mylonite fabric, but a later deformation affected both pseudotachylite and mylonite. The average chemical composition of the pseudotachylite veins reflects the composition of the host rocks, although the opaque, marginal crushed rock zones are enriched in iron and the fused centers are depleted in sodium. Glass is confined to crushed rock veins although not all crushed rock veins contain glass; apparently an increase in water pressure led to fusion.

Fahrig, W.F., Irving, E., and Jackson, G.D.

PALEOMAGNETISM OF THE FRANKLIN DIABASE; Can. J. Earth Sci., v. 8, no. 4, p. 455-467, 1971.

Robertson, W.A., and Fahrig, W.F.

THE GREAT LOGAN PALEOMAGNETIC LOOP - THE POLAR WANDERING PATH FROM CANADIAN SHIELD ROCKS DURING THE NEOHELIKIAN ERA; Can. J. Earth Sci., v. 8, no. 11, p. 1355-1372, 1971.

Fritz, W.H., and Palmer, A.R.

CONTRIBUTIONS TO EARLY MIDDLE CAMBRIAN FAUNAL ZONES; IN UPPERMOST PRECAMBRIAN AND LOWEST CAMBRIAN ROCKS IN SOUTHEASTERN IDAHO; by S.S. Oriel and F.C. Armstrong; U.S. Geol. Surv. Prof. Paper 394.

Froese, E.

THE GRAPHICAL REPRESENTATION OF SULFIDE-SILICATE PHASE EQUILIBRIA; Econ. Geol., v. 66, p. 335-341, 1971.

The oxidation and sulfidation of a particular (Fe, Mg) silicate mineral is most completely represented by means of composition contours on a log f_{O2}- log f_{S2} diagram. A part of these phase relations may be expressed in the form of ternary phase diagrams subject to certain stipulated restrictions, e.g., a constant f_{O2} or the presence of magnetite. It is possible to combine phase diagrams of several (Fe, Mg) silicates in order to display phase relations between these minerals and the iron sulfides in a tetrahedron representing a four-component system. And since sulfur is not a constituent of the silicate minerals, phase relations may be adequately shown on one side of the tetrahedron thus achieving a planar representation.

Garrett, R.G.

MOLYBDENUM, TUNGSTEN AND URANIUM IN ACID PLUTONIC ROCKS AS A GUIDE TO REGIONAL EXPLORATION, S.E. YUKON; Can. Mining J., v. 92, no. 4, p. 37-40, 1971.

Gordon, T.M.

SOME OBSERVATIONS ON THE FORMATION OF WOLLASTONITE FROM CALCITE AND QUARTZ; Can. J. Earth Sci., v. 8, no. 7, p. 844-851, 1971.

Gordon, T.M.

DETERMINATION OF INTERNALLY CONSISTENT THERMODYNAMIC DATA FROM PHASE EQUILIBRIUM STUDIES; Trans. Am. Geophys. Union, v. 52, no. 4, p. 379, 1971.

A technique has been devised for the evaluation of the internal consistency of experimental data in any particular chemical system. The sequence of steps is :

1) Each experimental point is expressed as an inequality in terms of the free energy change of the reaction to which it applies. That is, the sum $\Delta H_R - T\Delta S_R + RT\ln K$ is greater than zero if the reactants are stable or less than zero if the products are stable.
2) Linear relationships between enthalpies and entropies of different reactions are expressed as linear equalities by the application of Hess' Law.
3) The resulting system of inequalities and equalities is solved by the techniques of linear programming, maximizing and minimizing the entropy change and enthalpy change of each reaction in turn.
4) If the experimental data are internally consistent, the limits of each of the standard thermodynamic functions for each reaction are obtained. If the data are inconsistent, the offending experiments are identified.

The technique has been tested on the experimental results of six investigators in the system lime-alumina-silica-water-carbon dioxide.

Hacquebard, P.A., and Barss, M.S.

PALAEOGEOGRAPHY AND FACIES ASPECTS OF THE MINTO COAL SEAM, NEW BRUNSWICK, CANADA; Compte Rendu of 6th Carboniferous Congress, Sheffield 1967; v. III, p. 861-872, 1970-71.

The depositional sub-basin is interpreted as an abandoned river valley, bordered by pre-Minto lavas and slates. The valley was shallow, as revealed by palaeoslope of basement, and trended NE.-SW., as indicated in a lithofacies map of the roof rocks by four parallel sand tongues.

The regional seam development, determined from an isopach map, shows a surprisingly regular pattern, with an elongated optimum area in the centre. Petrographic correlations on ten column samples indicate that as time progressed coal formation contracted towards the centre, where the greatest thickness of 2-2 1/2 ft accumulated. An unexplored part of field may occur west of the known coal areas, but not on NE. side.

The coal lithofacies is based on microlithotype associations, and is determined in a four-component 'facies' diagram. A cross-section illustrates the facies changes in eleven time-rock units of the seam. In the shallower, NE. part of the forest-moor facies predominates, while in the deeper SW. portion the reed-moor facies is present. An open moor facies, extending over entire field, is four times represented.

Palaeobotanical aspects of the lithofacies types, as interpreted from miospore assemblages, support their respective assignments to specific swamp environments. The FM facies originating from a largely arborescent Lycopodophyta and the RM facies from a predominantly herbaceous Arthrophyta vegetation.

Sulphur, averaging 6.5%, occurs mainly in finely disseminated pyrite. It is highest in marginal areas where coal is thinner. No correlation with coal facies is represented and post-depositional origin immediately following burial of peat bog is advocated.

Havard, C.J.

LITHOSTRATIGRAPHIC STUDIES OF UPPER CRETACEOUS FORMATIONS ENCOUNTERED IN CPOG STRATHMORE EV 7-12-25-25; Bull. Can. Petrol. Geol., v. 19, no. 3, p. 680-690, 1971.

The lithology of the rock sequence recovered by continuous coring methods from the well CPOG STRATHMORE EV 7-12-25-25 W4 is described. This core provides a unique opportunity to examine a continuous series of the Late Cretaceous Horseshoe Canyon, Bearpaw, Oldman, and Foremost Formations.

Heginbottom, J.A.

LAND EVALUATION AT THE GEOLOGICAL SURVEY OF CANADA; Geographical Inter-University Resource Management Seminar 2(1), January 1972 (Department of Geography, Waterloo Lutheran University)

A description of the terrain evaluation and mapping program being undertaken by members of the Terrain Sciences Division, Geological Survey of Canada in the Mackenzie River Valley, N.W.T. The objectives of the

program are the inventory and the evaluation of performance of northern terrain, particularly permafrost terrain, as a basis for planning rational use of Canadian land, for managing man's engineering activities in the area, and for preventing unnecessary disturbance of the wilderness environment.

Achievement of these objectives is being undertaken through three concurrent approaches. These are (1) inventory mapping of the surficial geology deposits, their topography, texture and permafrost conditions, (2) assessment of the performance of earth materials in both their natural conditions and after disturbance, and (3) the production of a series of maps, showing both the inventory and the assessments, as a basis for regional planning.

Heginbottom, J.A.

SOME EFFECTS OF A FOREST FIRE ON THE PERMAFROST ACTIVE LAYER AT INUVIK, N.W.T.; in Proceedings of a Seminar on the Permafrost Active Layer, 4 and 5 May, 1971. (ed: R.J.E. Brown), Can. Nat. Res. Council, Associate Committee on Geotechnical Research, Tech. Memo. no. 103: p. 31-36, 1971.

The direct effects of forest fire on the permafrost active layer are relatively minor. Over the first few years the active layer becomes thicker, there is a slight decline in the ground surface elevation and the hummocky microrelief becomes less pronounced. More serious is the effect of bulldozing of fire-guards, where the vegetation-peat insulating mat is completely removed. The active layer thickens more and quicker, with a marked decline in surface elevation.

Several minor active layer earth flows occurred in the burned area, mainly on south facing slopes. Such flows are common in but not unique to fire areas. The connection between fire and slope failure is not established.

Hood, P.J.

GEOPHYSICAL APPLICATIONS OF HIGH RESOLUTION MAGNETOMETERS: Springer-Verlag, Berlin, Handbuch der Physik, v. 49, no. 3, p. 422-460, 1971.

The review begins with a description of the various types of nuclear magnetometers. Then the various ground, airborne, and satellite applications of high resolution magnetometers are discussed. The main applications of high resolution magnetometers may be summarized as follows:

a) In magnetic observatories to record the temporal variations of the Earth's magnetic field;
b) In archaeological investigations of buried sites of historical interest to delineate such features as kilns, ditches, walls, etc. Sunken iron ships are a relatively easy target to detect using high sensitivity magnetometers providing the general location is known and the depth of water is of continental shelf dimensions;
c) In satellite investigations of the magnetic fields of planets such as Earth and Venus, and
d) In mineral prospecting surveys both ground and airborne. Mineral exploration is potentially the most important application of high

resolution magnetometers because magnetic methods have been successfully used to locate mineral deposits for several centuries. A number of countries have been carrying out systematic aeromagnetic surveys of their territory and the results have indicated the value that these surveys have in geological mapping programs.

Of great interest to the petroleum industry is the evidence that experiments recently carried out with high resolution nuclear magnetometers have shown that detectable magnetic effects seem to be present in at least some sedimentary formations which give rise to "fine structure" in the recorded magnetic profiles. The development of high resolution magnetometers has also made feasible the measurement of the vertical gradient of the Earth's magnetic field by using two magnetometers separated vertically by a short distance. The effect of the diurnal variation of the Earth's magnetic field is thus eliminated in the resultant differential output, which is an especially desirable feature in diurnally-active areas. However, the use of high resolution airborne magnetometers necessitates a much better figure of merit for the magnetic compensation of the survey aircraft and the navigational requirements are much more stringent. Moreover the use of high resolution magnetometers has also necessitated that the aeromagnetic survey data be digitally recorded in order to make full use of the high resolution available. This procedure will therefore permit the compilation of the resultant magnetic maps to be automated as much as possible.

Hood, P.J.

MINERAL EXPLORATION: TRENDS AND DEVELOPMENTS IN 1971; Can. Min. J., v. 93, no. 2, p. 175-199, 1972.

This article reviewed the following topics for the year 1970:

1) New geophysical, geochemical, data recording, and compilation techniques.
2) New airborne and ground instrumentation.
3) New services offered by the survey companies.
4) The important articles on mineral exploration including reasearch and case histories.
5) Anything else which appeared to be of interest to those engaged in exploration for mineral deposits.

In the 1971 review the characteristics of commercially-available dip-angle, horizontal-loop, VLF and other types of ground electromagnetic equipment were tabulated.

Hood, P.J., and Bower, M.E.

AEROMAGNETIC RECONNAISSANCE OF THE NORTH ATLANTIC OCEAN, LABRADOR SEA AND BAFFIN BAY; Paper S9-45, 15th General Assembly, International Union of Geodesy and Geophysics, Moscow, July 30 - August 14, 1971.

Fifty-five low-level aeromagnetic profiles have been flown over the North Atlantic Ocean, the Labrador Sea and Baffin Bay using a North Star aircraft outfitted with digitally-recording magnetometers. Over the Reykjanes Ridge south of Iceland axial symmetry is detectable out to a distance of

500 km or so either side of the ridge (representing at least 60 million years of ocean floor spreading). South of the southern tip of Greenland the magnetic picture becomes somewhat confused due to the existence of fracture zones and a T-junction. A displacement of the ridge axis anomaly of 300 km was noted across the Charlie Fracture zone at 53°N latitude. The profiles indicate that the band of anomalies running parallel to the east coast of Greenland bend around the tip of Greenland. A correlation of the profiles from the Labrador Sea with those observed over the Reykjanes Ridge has been noted, suggesting that at least part of the spreading in the Reykjanes Ridge and the Labrador Sea was contemporaneous.

Using the geomagnetic polarity time scale it has been deduced that continental drift between Europe, Greenland and Canada commenced in the late Jurassic and terminated in the Eocene period some 38 million years ago. In the late Miocene (about 10 million years ago) ocean floor spreading recommenced in the North Atlantic Ocean but not in the Labrador Sea. Thus it is likely that the sedimentary rocks on the Labrador Shelf are mostly Mesozoic and younger in age, which makes the continental shelves bordering the Labrador Sea (and Baffin Bay) attractive for prospecting by the petroleum industry, in view of the fact that depth determinations on the profiles indicate that the thickness of sedimentary rocks on the outer Labrador Shelf exceeds 20,000 feet over a wide area.

Two zones of anomalies run up the Labrador Sea but are lost in the Davis Strait area. In central Baffin Bay the magnetic anomalies are quite flat but anomalies of 50 gammas amplitude having a wavelength of 20 km are discernible, indicating deeply buried sources. There is good evidence that the anomalies in the central part of Baffin Bay are linear in a northwest-trending direction over large distances, which would indicate that an oceanic crust exists below Baffin Bay. Geological models for profiles in the North Atlantic Ocean, Labrador Sea and Baffin Bay have been computed in which the dimensions and magnetizations of the various causative bodies have been calculated.

Hood, P.J., and McGrath, P.

THE AIRBORNE MAGNETOMETER, THE DIGITAL COMPUTER, AND GEOLOGICAL MAPPING; 73rd Annual General Meeting, Canadian Institute of Mining and Metallurgy, Quebec City, April 25-28, 1971.

In recent years there has been a revolution in aeromagnetic surveying techniques, and in the compilation and interpretation of the resultant data. Magnetometers with a greatly increased sensitivity have been introduced which have made feasible the development of aeromagnetic gradiometers. There is an ever increasing trend to the digital recording of aeromagnetic and navigation data during survey operations. This has permitted computer-oriented data compilation techniques to be devised which has resulted in a much more objective end product than is obtained by hand compilation and contouring methods. High resolution aeromagnetic maps show much more detail than standard sensitivity maps. Whereas the standard 10-gamma maps may be considered to support a 4-mile geological mapping program such as is carried out by the Geological Survey of Canada in the Precambrian Shield, high resolution aeromagnetic maps contoured at a one- or two-gamma contour interval are intended to support detailed geological mapping programs such as the provincial mines departments carry out. Quantitative interpretation

methods of magnetic survey data have also evolved to the point where the computer can be programmed to automatically yield solutions by 'best-fitting' the observed data with theoretical data generated by a geometrical model chosen by the interpreter as the most probable on geological and geophysical grounds. These methods are relatively cheap to apply and will revolutionize the quantitative interpretation methods which have been employed during the past two decades.

Irvine, T.N., and Baragar, W.R.A.

A GUIDE TO THE CHEMICAL CLASSIFICATION OF THE COMMON VOLCANIC ROCKS; Can. J. Earth Sci., v. 8, no. 5, p. 523-548, 1971.

Jonasson, I.R., and Boyle, R.W.

GEOCHEMISTRY OF MERCURY AND ORIGINS OF NATURAL CONTAMINATION OF THE ENVIRONMENT; Can. Inst. Mining Met., Trans., v. LXXV, p. 8-15, 1972.

Current interest in the distribution of mercury in the natural environment comes from quite different, though not unrelated, sources. Mercury has long been an important metal in many industries and has, therefore, been much sought after by mining interests. The presence of mercury traces in the various media of the natural evironment, namely soil, rock, air, water and vegetation, is exploited by geochemists not only to find mercury and polymetallic ore deposits, but also to find most other types of economic metal mineralization.

More recently, however, mercury has caught the attention of health authorities and environmental scientists who are becoming increasingly concerned over the hazards of mercury wastes and the danger these present to the environment and to man. It is now apparent that the trace quantities of mercury, considered so important and helpful to exploration geologists, can be concentrated in the biosphere to such levels as to present considerable problems for ecologists.

This article summarizes most of the available data on mercury contents in materials of geological interest and presents average normal values for rocks, ores, minerals, soils, sediments, waters and plants. The geochemical cycle for mercury in nature is presented and the mechanisms of mercury migration around the cycle are discussed.

Jones, F.W., and Horton, R.E.

A DATA ACQUISITION SYSTEM WITH COMPUTER CONTROL FOR AN OPTICAL EMISSION SPECTROMETER; Can. Spectroscopy, v. 16, no. 3, p. 1

A computer controlled data acquisition system for an optical emission spectrometer, which can be assembled using standard component parts of computer hardware and a custom built scanning unit, is described.

Kerr, J.W., and Thorsteinsson, R.

PRELIMINARY SUBMISSION FOR SILURIAN-DEVONIAN STRATOTYPE, CANADIAN ARCTIC ARCHIPELAGO; Geological Newsletter, v. 1971, no. 4, Quart. J.; issued by the International Union of Geological Sciences.

In much or all of the Archipelago the boundary between the Silurian and Devonian Systems is transitional and not represented by a hiatus. Moreover the boundary is represented in four different facies: graptolitic, shelly, coarse quartzose clastics, and flysch.

Two of the most informative sections of the Silurian-Devonian boundary are at Twilight Creek, central Bathurst Island, and Washington Point, Baillie Hamilton Island. Because of the climate, accessibility and the fact that research in Upper Silurian and Lower Devonian rocks is at an early stage, the writers suggest that the Archipelago should not be considered as a possible Silurian-Devonian stratotype.

Kerr, J. Wm.

GEOLOGY OF OUTSTANDING ARCTIC AERIAL PHOTOGRAPHS; 2. Schei Summit Area, Central Ellesmere Island; Bull. Can. Petrol. Geol., v. 20, no. 1, 1972.

Aerial photograph A16678-28 of the Schei Summit area, central Ellesmere Island, displays a remarkable stratigraphic section over 20,000 feet thick, including 14 Paleozoic formations and one each of Proterozoic and Cretaceous to Tertiary age. The column includes one disconformity and three angular unconformities, one of which is markedly angular locally. Type sections of the Ordovician Cornwallis Group and of its three formations were chosen here. Nearly all the Schei Summit area is part of a single allochthonous block underlain by the Parrish Glacier thrust.

Klassen, R.W.

NATURE, THICKNESS AND SUBSURFACE STRATIGRAPHY OF THE DRIFT IN SOUTHWESTERN MANITOBA; Geol. Assoc. Can., Sp. Paper 9, p. 253-261, 1971.

In southwestern Manitoba the drift has approximately equal proportions of till and stratified sediments on the uplands and in lake basins, and mainly till on the plains. The tills comprise nearly equal amounts of sand, silt and clay with minor amounts of gravel. Drift thickness averages about 200 feet but is highly variable. On Duck Mountain upland the drift is 600 to 1,000 feet thick; it ranges from less than 10 feet to 500 feet on other uplands and adjacent plains.

Subsurface units are recognized mainly by their stratigraphic positions, carbonate content and texture of the tills. Each unit commonly comprises several beds of till and stratified sediments. Within the Duck Mountain upland the drift succession is separated into five units, informally designated A to E from oldest to youngest. Farther south, within the Souris basin and Souris River plain, four units (Souris gravel and sand, B, C and D) and three units (A, B, C) respectively are recognized.

The youngest units are of probable Wisconsin age and include the previously described Shell Till, Roaring River Clay, Minnedosa Till, Lennard Till or their time stratigraphic equivalents. The older units are pre-Wisconsin.

Kornik, Leslie J.

MAGNETIC SUBDIVISION OF PRECAMBRIAN ROCKS IN MANITOBA; Geol. Assoc. Can., Sp. Paper 9, p. 51-60, 1971.

This paper presents a separation of Manitoba's Precambrian rocks into magnetically similar areas or subdivisions. These subdivisions differ magnetically, in textures and patterns of magnetic anomalies, and geologically, in the type and intensity of metamorphic events. Although subdivisions differ from each other, within a single subdivision the different types of data correlate. These data are combined in an attempt to present a coherent interpretation of the major structural features present in Manitoba.

Williams, R.M., Little, H.W., Gow, W.A., and Berry, R.M.

URANIUM AND THORIUM IN CANADA: RESOURCES, PRODUCTION AND POTENTIAL; Atomic Energy, Can., Paper No. A/Conf. 49/A/154.

The history of Canada's uranium industry is marked by a period of rapid expansion in the 1950's and an equally dramatic decline in the 1960's. Although short-term markets are weak, the industry looks forward with optimism to new expansion in the mid-1970's, based on the demand for nuclear fuel.

Uranium production has been entirely from the southern and western parts of the Canadian Shield. The greatest production, reserves, and short-term potential are from uraniferous quartz-pebble conglomerates in Early Proterozoic sedimentary basins. Vein and replacement deposits have provided much uranium, and minor production has come from pegmatitic deposits. However, rocks younger than Precambrian that are also geologically favourable for uranium are widespread, and are expected to yield significant deposits.

Canadian conglomeratic uranium ores contain significant quantities of thorium, available as a byproduct of uranium. Thus, Canada is potentially a major world supplier of low-cost thorium.

The various Canadian ore types have been processed with either the acid-sulphate or the carbonate-bicarbonate leaching system, and the methods used to recover uranium from the leach liquors produced have included ion exchange, solvent extraction, and direct precipitation. However, investigations have indicated numerous possibilities of modifying the proven techniques in the design of future Canadian plants to reduce costs, and to produce high-purity uranium as well as thorium and rare-earth byproducts.

Canadian capabilities and techniques have been developed for refining and converting uranium concentrates to the various chemical and physical forms required by reactor fuel fabricators. Significant quantities of orange oxide (UO_3), ceramic oxide powder (UO_2), uranium hexafluoride (UF_6), uranium metal, and alloys of uranium metal have been produced.

Only a fraction of Canada's known low-cost uranium reserves and its mining and refining capabilities are presently committed; its unexplored potential is great. Canada's future in uranium supply is excellent.

Lowdon, J.A., Robertson, I.M., and Blake, W., Jr.

GEOLOGICAL SURVEY OF CANADA RADIOCARBON DATES XI; Radiocarbon, v. 13, no. 2, p. 255-324, 1971.

Two-hundred and forty-seven radiocarbon age determinations on geological samples made by the Geological Survey of Canada Radiocarbon Dating Laboratory are reported. They are on samples from various areas as follows: Newfoundland, including Labrador (13); Nova Scotia (16); Prince Edward Island (1); New Brunswick (1); Quebec (11); Ontario (38); Manitoba (23); Saskatchewan (1); Alberta (25); British Columbia (34); Yukon (12); Northwest Territories–Mainland (20); Northwest Territories–Arctic Islands (47); Svalbard (5). Many of the ages reported have been corrected for isotopic fractionation.

Details of the new 1-L proportional counter are given, and results obtained with this counter are shown to compare favourably with those of the 2-L and 5-L counters. Further investigations of bone dating (collagen fraction) indicate that a somewhat purer gas is obtained by precipitating the CO_2 evolved after combustion as $SrCO_3$ and then liberating CO_2 again with H_3PO_4. Ages obtained by normal and $SrCO_3$ preparations from the same bone samples agree closely.

Macqueen, R.W., Ghent, E.D., and Davies, G.R.

MAGNESIUM DISTRIBUTION IN LIVING AND FOSSIL SPECIMENS OF THE ECHINOID PERONELLA LESUEURI AGASSIZ, SHARK BAY, AUSTRALIA; Prog. Abstracts, VIII Intl. Sed. Cong. 1971, p. 64.

About 100 spot analyses by electron microprobe of magnesium distribution in calcite coronal plates of the clypeasteroid echinoid Peronella lesueuri collected live from Shark Bay, Western Australia (113°30'E, 25°30'S) indicate an average content of 12.8 mol % $MgCO_3$. While this average agrees with X-ray diffraction data, point-to-point compositional variations ranging from about 10.4 to 15.2 mol % $MgCO_3$ indicate appreciable heterogeneity in Mg distribution. This heterogeneity is not related obviously to the crystal fabric or the particular coronal plate analysed.

More than 100 spot analyses of Pleistocene (>30,000 yrs. B.P.) specimens of P. lesueuri from the Carbla Oolite in eastern Shark Bay show that coronal calcite averages about 3.6 to 4.0 mol % $MgCO_3$, yet there is a range in point-to-point composition from 1.4 to 15.2 mol % $MgCO_3$. No dolomite was encountered. The Mg-rich domains exceeding 4 mol % $MgCO_3$ appear to be $< 5\mu$ in diameter, are not distinguishable optically, and are not related obviously to either crystal fabric or the particular plate analysed. The Mg-rich domains appear to be residuals which have partly or completely escaped Mg-loss in the stabilization process; whether incongruent solution or microscale solution and reprecipitation. The Mg-rich calcite domains could be the location of dolomite nucleation at a later stage in diagenesis.

Maxwell, J.A.

THE CONTINUING PAST: THE GROWTH AND DEVELOPMENT OF LABORATORY FACILITIES IN THE GEOLOGICAL SURVEY OF CANADA; Fourth Ceramic Chemists' Conference (On Silicate Analysis); Brit. Ceram. Res. Assoc. Sp. Publ. no. 72, p. 61-69, 1971.

The development of laboratory facilities in the Geological Survey of Canada, as related to the growth of Survey activities since its founding by William Logan in 1842, are briefly reviewed. Emphasis is placed upon the work done, methods and equipment used, and type and volume of scientific data produced in the Analytical Chemistry, Geochemistry and Mineralogy Sections.

McCrossan, R.G., and Procter, R.M.

MINERAL POTENTIAL OF ARCTIC CANADA; Univ. Missouri Rolla J., no. 2, p. 31-37, 1971.

Canada is on the threshold of a major new phase in the development of its Arctic resources. The Prudhoe Bay discovery triggered a boom in northern petroleum exploration that is just getting into high gear this year. Mining activity also has greatly expanded in the last few years with some 73 active exploration programs underway and several large new mines just coming into production. The size of these ventures is indicated by ore reserves of two lead-zinc mines to the value of 900 million dollars at Pine Point in southern Northwest Territories, and 1.2 billion dollars at the Anvil property in the southern Yukon Territory. Other properties with very large reserves are currently under development.

Approximately 465,000 square miles of the 1.5 million square miles of Canada north of the 60th parallel are underlain by sedimentary rocks. A volumetric estimate of petroleum potential on the basis of rather scanty evidence is made at 54 billion barrels. With the current activity in the area it should by possible to improve this estimate considerably in the next 2 or 3 years. The two most promising areas are the Arctic Coastal Plains containing large volumes of young sedimentary rock and large structures, and the Mesozoic Sverdrup Basin also with many potential hydrocarbon traps. The Interior Plains of the mainland and the Arctic lowlands, as well as the fold belts of the Franklinian miogeosyncline indicate lesser potential.

McDonald, B.C.

LATE QUATERNARY STRATIGRAPHY AND DEGLACIATION IN EASTERN CANADA; in Turekian, K.K., (editor), The Late Cenozoic Glacial Ages, Yale University Press, p. 331-353, 1971.

Stratigraphic and radiocarbon data from four "control areas" have been used to reconstruct the areal extent and succession of Wisconsin glacial phases and intervening interstades in eastern Canada between Quebec and Manitoba. Three important Wisconsin glacial phases are represented, separated by the early Wisconsin St. Pierre interstade and by the mid-Wisconsin Port Talbot interstade. Limits of glacier retreat during the St. Pierre and Port Talbot interstades are postulated. Influence of the earliest

Wisconsin glacial phase was concentrated in eastern Canada and did not extend west to Manitoba. Both post-St. Pierre glacial phases were more extensive than the earliest Wisconsin glacial episode, and they affected areas farther west. The early Wisconsin ice sheets grew in eastern Canada, but evidence of ice flow directions between Manitoba and Quebec indicate that the mid-Wisconsin Port Talbot interstade was accompanied by a westward shift of the centers of glacier outflow. Some characteristics of late Wisconsin deglaciation are discussed, the influences of which may be recognizable in deep-sea sediments bordering the continent.

McDonald, B.C., and Banerjee, Indranil

SEDIMENTS AND BED FORMS ON A BRAIDED OUTWASH PLAIN; Can. J. Earth Sci., v. 8, p. 1282-1301, 1971.

Sediments and bed forms from three braided outwash plains and one steep non-braided mountain stream in the Rocky Mountains of Alberta are compared to sediments and structures exposed in a paleo-outwash sequence.

Channel sediments are subdivided into (a) pool facies: ripple- and parallel-laminated silty sand, with current crescents around isolated stones; and (b) riffle facies: parallel-stratified gravel and silt or silty sand.

'Transverse ribs' constitute a bed form typical of riffle portions of channels. This bed form occurs as a train of regularly spaced pebble, cobble, or boulder ridges oriented transversely to the flow. Locally, the pebbly ribs are separated by, and rest on, a stone-free silty substratum. It is suggested that transverse ribs constitute a common equilibrium bed form in higher gradient riffle portions of gravelly alluvium.

Longitudinal bars dominate interchannel areas of the modern outwash plains. They consist of coarse, poorly sorted gravel, either massive or exhibiting crude horizontal stratification. The paleo-outwash, composed of finer-grained and better sorted gravel, is characterized by sets 5 to 30 cm thick of cross-stratified sand and by sets 75 to 82 cm thick of cross-bedded pebble gravel. These may be related to progradation of dunes and bars, respectively.

Standard deviations of channel azimuths in modern outwash plains are appreciably less than that recorded by cross-stratification measurements in the time-transgressive sequence of paleo-outwash. This is partly due to the braided system of channels having swept from side to side across the plain through time.

McDonald, B.C.

FLUVIAL SEDIMENTATION ASSOCIATED WITH SUBGLACIAL STREAMS; Geol. Soc. Am., Abst. Prog., v. 4, no. 1, p. 31-32, 1972.

The esker near Windsor, Quebec, was deposited from a subglacial stream that entered a glacial lake at a depth of 105 metres. Flow entering the lake from the tunnel mouth deposited a succession of subaqueous fans, now topographic "beads", each characterized by thick wedges of coarse gravel inter-tongued distally with finer sand that grades in turn into lake-bottom sediments. Single normal faults with large displacement are centrally located in these fans. Deposition within the tunnel produced a single uniform ridge

characterized by vertically stacked cycles of sediment and by closely spaced high-angle reverse faults, with large net cumulative displacement, located on the ridge flanks. Variances of paleocurrent measurements are 3000 to 6000 in beads and 1000 to 2000 in ridges, reflecting lateral constraint on flow direction imposed by the tunnel walls. Subglacial tunnels flowing full are gigantic natural pipes in which bed forms that depend on surface water waves cannot be stable. Thus structures deriving from anti-dunes should be absent. Aggradation of thick sequences, while maintaining limited depth and relatively constant bed shear stress, is probably accomplished by a melting upward of the ice roof. Within-tunnel sediments are characteristically sand and gravel with uniform tabular sets of large-scale crossbedding. Thick sections of fluvially crossbedded sediments occur commonly beneath deep-water sediments, marine or fresh-water, in postglacial sequences. They do not necessarily imply an episode of essentially subaerial conditions. Rather they may reflect high bed shear stress due to an ice "lid" having reduced the flow cross-section through which basal meltwater must discharge.

McLaren, D.J.

ENERGY VERSUS ENVIRONMENT—THE ARCTIC DILEMMA; Can. Mining Met. Bull., v. 64, p. 68-73, 1971.

Arctic Canada is one of the largest undeveloped terrains remaining in the world, and is in many ways unique. The ecological balance of the region is more delicate than tropical or temperate regions of similar size. This region is likely to be developed by research for and production of resources, primarily petroleum, in the immediate future. As well as sensitive terrain surface caused by permafrost in some areas, many large and small mammals and birds are also in a delicate balance with the environment. Small changes in this balance can have large effects.

The probability of finding petroleum in different regions varies widely, but already there are good indications on the mainland and in the Islands that both oil and gas are present. Geophysical work in the offshore, particularly the Beaufort Sea, suggests further promising potential. Possible reserves in the Islands and mainland Arctic may amount to 50 or more billion barrels.

A responsible approach to problems facing exploitation in an Arctic environment includes the careful monitoring by industry of likely effects of their activities. The Mackenzie Valley Pipeline Research Association test loop at Inuvik provides an example of such monitoring. Outside Canada, the operations at Prudhoe Bay on the north coast of Alaska show how major companies may operate responsibly and reduce environmental interference to a minimum. Nevertheless, four variables must affect any decisions to be made concerning energy resource exploitation in the Arctic. These are man's need for energy, economic and industrial pressures to develop energy sources, the desire to preserve a deteriorating environment, and the role of government as representing all individuals in the country and their several points of view. Factors that must be taken into account in making any decisions include the importance of Canadian oil in a world picture, the need for alternative sources of energy in the near future, the depletion of nonrenewable resources at an accelerating rate and the increasing awareness that the major problems facing man have no direct technical solution and that social or political decisions must precede further technological development.

Nassichuk, W.W.

PERMIAN AMMONOIDS AND NAUTILOIDS, SOUTHEASTERN EAGLE PLAIN, YUKON TERRITORY; J. Paleontol., v. 45, no. 4, p. 1001-1021, 1971.

Lower Permian ammonoids and nautiloids are known from two horizons in the upper part of the Jungle Creek Formation along the banks of the Peel River, northern Yukon Territory. Upper Artinskian ammonoids, Paragastrioceras jossae subtrapezoidale, Paragastrioceras jossae exile, and Uraloceras involutum occur in black shales near the top of the formation at one locality. Some twenty miles northeast of the Artinskian occurrence, early Sakmarian (late Wolfcampian) ammonoids and nautiloids occur at two localities in interbedded shales and limestones in the same formation. Included are the ammonoids Prothalassoceras bostocki n. sp., Eoasianites aff. E. trapezoidalis, Somoholites cf. S. beluensis, Properrinites furnishi n. sp., Medlicottia n. sp., Tabantalites bifurcatus, ?Uraloceras sp. and Uraloceras cf. U. irwinense and the nautiloids Liroceras sp. and Titanoceras sp. Genera in the Artinskian fauna on the Peel River characterize a boreal realm and are known to occur elsewhere in the northern Yukon and in the Canadian Arctic Islands. Several genera in the Sakmarian faunas, Properrinites, Tabantalites, Liroceras and Titanoceras, are unknown elsewhere in Canada. Properrinites is unknown elsewhere from a comparable sub-Arctic latitude, and its direct association with boreal elements such as Uraloceras, Somoholites, and Tabantalites is unique. The fauna containing these genera provides new data on correlation between lower Sakmarian strata in the Ural Mountains and upper Wolfcampian strata in west Texas. A single specimen of Uraloceras sp., long known in the literature from southeastern British Columbia, near Fernie, is described and illustrated.

Norford, B.S.

SILURIAN STRATIGRAPHY OF NORTHERN MANITOBA; Geol. Assoc. Can., Sp. Paper 9, p. 199-207, 1971.

Outcrops of Silurian rocks are extremely rare and mostly restricted to the coastal regions of Hudson Bay. The bulk of the knowledge of Silurian stratigraphy is derived from study of samples from several wells drilled in the Hudson Bay Lowlands.

The Silurian succession consists of two sequences. The lower sequence is mostly limestone and rests unconformably on Precambrian rocks at the coast near Churchill and on the Port Nelson Formation and Upper Ordovician carbonate rocks farther inland. The Severn River, Ekwan River and Attawapiskat Formations comprise the lower sequence and are mostly Lower Silurian (Middle and Upper Llandovery). The Attawapiskat may be in part Middle Silurian (Wenlock) and in part is coeval with the Ekwan River and lower Kenagami River Formations. Most of the Port Nelson Formation is uppermost Ordovician but the upper part may be Lower Llandovery. The upper sequence is an evaporitic suite of rocks: mudstone, dolomite and anhydrite of the Kenogami River Formation. This sequence essentially lacks fossils but probably represents much of the interval Middle Silurian (Wenlock) to Lower Devonian.

Bioherms are well developed in the Attawapiskat Formation; this unit and the underlying Silurian formations could form potential reservoir rocks for oil and gas both on the mainland and offshore beneath Hudson Bay, provided that suitable geological structures are present to form traps. No obvious source rock for petroleum is known older than Silurian in northern Manitoba but thin oil shales have been described within the Ordovician of Southampton and Coates Islands and perhaps may extend southward beneath Hudson Bay.

Norris, A.W., and Uyeno, T.T.

STRATIGRAPHY AND CONODONT FAUNAS OF DEVONIAN OUTCROP BELTS, MANITOBA; Geol. Assoc. Can., Sp. Paper 9, p. 209-224, 1971.

Devonian rocks underlie the southwestern and northeastern parts of Manitoba in two sedimentary basins separated by the Canadian Shield. The better-known, southwestern Manitoba sequence, exposed in the Lake Winnipegosis–Lake Manitoba area, comprises Middle and Upper Devonian formations of the Western Canada Sedimentary Basin. These are: Ashern red beds (Eifelian or older), Elm Point mottled dolomitic limestone (late Eifelian and probably younger), Winnipegosis reefal and inter-reefal dolomites (Givetian), Dawson Bay limestone, argillaceous limestone and shale (Givetian), and Souris River limestone, argillaceous limestone and shale (early Frasnian). The northeastern Manitoba sequence underlies the drift-covered Cape Tatnam coastal region of the Hudson Bay Lowlands. It comprises Lower, Middle, and probably Upper Devonian strata of the Hudson Bay Basin. The Devonian succession penetrated in the Kaskattama No. 1 well is: upper carbonate member of the Kenogami River Formation (Gedinnian), Stooping River limestone and dolomite (Emsian), and Kwataboahegan fragmental limestone (early Eifelian).

Conodonts of the southwestern Manitoba Devonian sequence indicate the following relationship: elements indicative of Eifelian, and probably late Eifelian, age occur in the basal Elm Point Formation. The Winnipegosis Formation contains Spathognathodus brevis which, in Germany, ranges throughout the Polygnathus varcus Zone and younger. Polygnathus alveoliposticus and Icriodus eslaensis are present in the Dawson Bay and are assignable to the P. varcus Zone, suggesting the possible close contemporaneity of the Winnipegosis and Dawson Bay Formations. A Spathognathodus insitus fauna of early Upper Devonian age characterizes the Souris River Formation.

Norris, D.K.

THE GEOLOGY AND COAL POTENTIAL OF THE CASCADE COAL BASIN; in A Guide to the Geology of the Eastern Cordillera along the Trans Canada Highway between Calgary and Revelstoke; ed. I.A.R. Halladay and D.H. Mathewson; publ. by Alta. Soc. Petrol. Geol.

The Cascade coal basin is defined as the area underlain by the coal-bearing Kootenay Formation in the immediate footwall of the Mount Rundle thrust. It extends for 50 miles northwestward from Mount Blane in Opal Range to the north end of Cascade Mountain. Depositionally the Kootenay

there can be interpreted as an integral part of a delta system embracing all the Kootenay occurrences in the southeastern Canadian Cordillera. Stratigraphically the succession is completely developed on Mount Allan about midpoint along the axis of the basin, but is progressively truncated by the Mount Rundle fault to the north and south of this point. Thus at the extremities only the lowest beds of the formation are present. At maximum there are about 12 coal seams whose average thicknesses are five feet or greater. All comprise low volatile bituminous or semi-anthracite coals. Their anomalously high rank may be due to thermal upgrading during and since the Laramide orogeny. Structurally the basin is essentially an asymmetric to overturned syncline in the Lacs des Arcs thrust plate. In the core of the syncline folding has greatly increased the lengths of the surface traces of the seams and added significantly to the amount of readily accessible coal. Away from the core the measures dip gently southwest on the northeast flank and are near vertical on the southwest flank. Abundant slickensides on bedding attest to the fundamental control of the lithologic layering in buckling and differential translation within the Lacs des Arcs plate.

It is estimated that less than 200 million tons of low ash, low-sulphur coals are available for underground mining in seams five feet or greater in thickness within one-half mile of the surface, in the southern two-thirds of the basin which lies outside of Banff National Park. At an average rate of extraction of five million tons per year, the basin could be exhausted by the year 2000.

Norris, D.K.

FRACTURES AND FAULTS IN THEORY AND PRACTICE IN THE CANADIAN CORDILLERA; Geol. Assoc. Can., Cordilleran Mtg., Feb. 1972, Abstr. Prog.

Structural discontinuities impressed on the rocks of the Canadian Cordillera range from fractures with no discernible displacement (joints) to faults with displacements as much as tens of miles. The fractures visible to the naked eye and identified as joints cut the rock into discrete, polyhedral fragments commonly less than a few feet on a side. They occur in all ages and types of igneous, metamorphic and sedimentary rocks, and although the most pervasive and common structural features impressed upon the crust, they are perhaps the least understood. Characteristically they have no features on their surfaces which allow them to be subdivided genetically so that a laborious and often ambiguous nomenclature based on spatial relations and prominence has evolved to identify the various elements of a fracture pattern.

Four observations are prime considerations in any theory of the origin of fractures: first, fractures are a brittle phenomenon and as such must develop within the upper 20,000 feet of the crust; second, nearly all joints, regardless of age, show no evidence of displacement along them; third, joints are commonly perpendicular or sub-perpendicular to the layering in stratified rock masses and fourth, surface features on many fractures are identical with those produced in metals under tensile failure conditions. In the light of these observations the author considers that joints are a shallow rock phenomenon and he subscribes to the proposal that joints are due to regional tensile stresses which are attendant upon uplift. There is, therefore, only motion across the joints and not along them as they are formed.

In sedimentary and metamorphic rocks, these stresses arise from uplift with concomitant erosion and relaxation, and joint orientations may be controlled by residual tectonic stresses. In igneous rocks there are, in addition, joints caused by tensile stresses due to thermal contraction.

Faults, on the other hand, are classified more easily genetically because they commonly cut and displace marker horizons and they have diagnostic features on their surfaces. Nonetheless, a cumbersome and ambiguous nomenclature has evolved here as well, largely because of the persistent use of an orthogonal system of horizontal and vertical reference axes. Thus a "normal" fault can by definition become a "reverse" fault and vice versa in the structural development of an orogenic belt if the fault is externally rotated through the vertical.

Where it is possible to utilize bedding or other reference surfaces for two of the three orthogonal axes, however, the faults can be divided into those which lengthen and thin the rock succession (extension faults), those which shorten and thicken the succession (contraction faults), and those along which the displacement is largely transcurrent. Recognition of the omission, repetition or simple translation of rock masses is of fundamental importance to the exploration for, and development and exploitation of mineral occurrences, in addition to a clearer understanding of the structural history of the region. Extension and transcurrent faults may strike in any direction but those with large displacements commonly parallel the regional structural grain. Contraction faults, on the other hand, characteristically parallel this grain regardless of displacement. Stratigraphic separation on these macroscopic faults ranges from that which is barely visible to several thousands of feet.

Theory would predict that both fractures and contraction faults can be the product of one and the same system of compressive stresses. Thus for the Laramide deformation in the eastern Canadian Cordillera one might anticipate a system of conjugate contraction faults with angular relations in cross-section similar to those observed in laboratory compressive destructive tests. The faults would strike parallel to the Cordillera, with one set dipping east and the other west. The associated fracture pattern should consist of conjugate sets parallel and subparallel to the faults and some displacement on individual fractures could be expected. In practice, however, the Laramide deformation there is decidely asymmetric and west-dipping contraction faults (thrusts) are most common. Only in parts of the northern Cordillera do east- and west-dipping contraction faults occur together in approximately equal numbers, and fracture sets parallel and subparallel to them are rare. There, as elsewhere in the eastern Canadian Cordillera, the joints in the sedimentary veneer are characteristically perpendicular or sub-perpendicular to bedding.

Since the time of Agricola a plausible hypothesis is that the source of metals and gangue elements for hydrothermal deposits has been the country rock. Laboratory measurements indicate that at depths greater than about 20,000 feet, rocks are impermeable for all practical purposes. Hence the mineral fillings and coatings along joints and faults indicate that these structural discontinuities must have become dilated at somewhat shallower depths and provided at least local permeability for ore-bearing solutions.

The history of the Canadian Cordillera is one of many cycles of subsidence, compression, uplift, erosion and dilation so that joints and faults could have formed and been mineralized within depths of about three miles measured from several ancient erosion surfaces. Some rock masses which

have survived destruction through erosion in the geological past may, therefore, have been favourably positioned for mineralization on more than one occasion and the chances of their containing hydrothermal deposits are proportionately greater. Intimate knowledge of the geologic history of the Cordilleran orogen can provide a scientific basis for the discovery of these masses and enhance meaningful, qualitative estimates of the mineral potential of the Canadian Cordillera.

Norris, D.K.

TECTONIC COMPLEX, NORTHERN YUKON TERRITORY AND WESTERN DISTRICT OF MACKENZIE, CANADA; Geol. Soc. Am., Abstr. Prog., v. 3, no. 6, p. 398-399, 1971.

The tectonic complex of northern Yukon Territory and western District of Mackenzie comprises fault and fold structures of diverse ages and trends in relatively unmetamorphosed, laterally discontinuous, layered sedimentary sequences, of Phanerozoic and late Precambrian age. Acid igneous intrusions occur locally in pre-Mississippian rocks and basic igneous sills and dykes are widespread in the Precambrian. The complex forms the structural and stratigraphic link between the fault and fold belts of Mackenzie Mountains and those of northern Alaska.

The Mackenzie Mountain fold belt trends in a northerly direction, then toward the west in a great arc and ends abruptly against the fault blocks of Wernecke and Richardson Mountains. It is dominated by upright, open folds some of which are linked en échelon and others are paired. Steeply dipping faults parallel to fold axes have significant vertical and possibly lateral separation. In Richardson Mountains the principal tectonic elements are ancient, near-vertical, south-trending faults which were active in the late Precambrian, early Paleozoic, Late Cretaceous and ?early Tertiary. Some of these faults now have right-lateral separation. They turn southeastwards in Wernecke Mountains and allowed thrust repetition of the early Paleozoic and Precambrian layered successions there. Strike-slip displacements in the Richardsons and thrust displacements in the Werneckes in one and the same fault system may be at least in part the result of common ?Late Cretaceous orogenic stresses. Immediately to the west in the Taiga Ranges, open, upright folds, cut by moderately dipping thrust faults, trend northwest parallel to the structural grain in Wernecke Mountains, then west and plunge into the depression linking them with the Nahoni Range fold belt. The north-trending, open folds in Paleozoic and Late Precambrian rocks of Nahoni Range are flanked on the west by a major, north- and northeast-trending belt of ?early Tertiary, west-dipping thrust faults which repeat the Late Precambrian, Paleozoic and Mesozoic layered sequences along the Yukon-Alaska border. Between Nahoni Range and Richardson Mountains lies the north-trending fold belt evident in Upper Cretaceous clastic rocks of Eagle Plain. The folds of Nahoni Range, Ogilvie Mountains, Eagle Plain and Richardson Mountains are interrupted or terminated against Aklavik Arch, a major, composite, tectonic feature, extending from Beaufort Sea southwestward to Alaska. This arch was active in the ?Late Devonian, ?Late Carboniferous to Early Permian, Early and possibly Late Cretaceous and was fundamental in controlling erosional, depositional and structural patterns through much of Phanerozoic time.

The northern Richardson Mountains are characterized by broad, ovate domes, flanked by near-vertical, strike-slip faults, active in the Late Cretaceous and early Tertiary. The structures in the northern Richardsons swing northeast parallel to Aklavik Arch and plunge beneath Mackenzie Delta. North- and northeast-trending, near-vertical faults dominate the structural style of the Mesozoic clastic cover as far west as Barn Mountains. There, the trend of elongate domes and faults swings to the northwest, parallel to the ?Early Devonian structural grain of British Mountains. West- and southwest-dipping ?Late Cretaceous thrust faults on the north flank of Old Crow Basin increase in number and magnitude of horizontal displacement westwards between Barn Mountains and Brooks Range. The thrust plates and the basement of acutely folded and faulted sequences of clastic and carbonate rocks of British Mountains link the tectonic framework of the Canadian Foreland thrust and fold belt with its counterpart in northern Alaska.

Overton, A.

SEISMIC EXPERIMENTS ON THE QUIRKE LAKE SYNCLINE, ONTARIO; Geol. Assoc. Can. - Proc., v. 24, no. 2, 1972.

In 1966 and 1967, experiments were conducted on the Quirke Lake syncline to determine whether the seismic method could be used to locate basement structures associated with uraniferous ores. Both seismic refraction and reflection methods were tried yielding seismic velocity information which may be useful in designing similar experiments. Within the localities tested and with the methods tried, little hope is indicated for the success of seismic methods in this Huronian system. Some suggestions for future experiments are to use surface energy sources rather than drilled shotholes, to use controlled frequency sources, and to use cross-correlation methods between source and receiver signals.

It is emphasized, however, that the seismic method has been successful in mapping strata of Precambrian environments elsewhere, and the merits of the method must be determined separately for each prospective area.

Pedder, A.E.

LOWER DEVONIAN CORALS AND BRYOZOA FROM THE LICK HOLE FORMATION OF NEW SOUTH WALES; Palaeontology, v. 14, pt. 3, p. 371-386, 1971.

Rampton, Vern

LATE PLEISTOCENE GLACIATIONS OF THE SNAG-KLUTLAN AREA, YUKON TERRITORY; Arctic, v. 24, p. 277-300, 1971.

Two late Pleistocene limits of glaciation were delineated in the Snag-Klutlan area. Radiocarbon dates, surficial characteristics of its drift, and the palynology of overlying sediments imply the older glaciation (Mirror Creek) is early Wisconsin in age; the younger glaciation (Macauley) is late Wisconsin in age and culminated c. 13,700 B.P. The stratigraphy of deposits within the Macauley glacial limit implies that deglaciation between the two glaciations was minimal.

Rampton, Vern

LATE QUATERNARY VEGETATIONAL AND CLIMATIC HISTORY OF THE SNAG-KLUTLAN AREA, SOUTHWESTERN YUKON TERRITORY, CANADA; Geol. Soc. Am. Bull., v. 82, p. 959-978, 1971.

Present vegetation in the Snag-Klutlan area has a general altitudinal zonation; tree line being between 4100 and 4400 ft elevation on almost all slopes. Pollen spectra from surface samples below tree line generally reflect the vegetational composition. Those from above tree line, however, do not always reflect the surrounding vegetation, because they contain a large amount of pollen originating from below tree line.

A pollen diagram from pond sediments suggests the following vegetational sequence for the last 31,000 yrs: 31,000 B.P. through 27,000 B.P., fell-field or sedge-moss tundra followed by shrub tundra; 27,000 B.P. through 10,000 B.P., sedge-moss tundra; 10,000 B.P. through 8700 B.P., shrub tundra; 8700 B.P. through 5700 B.P., spruce woodland; 5700 B.P. through present, spruce forest. The diagram also suggests the following negative departures of July temperatures: 31,000 B.P. through 27,000 B.P., at least 8°F and possibly as much as 16°F; 27,000 B.P. through 13,500 B.P., 13°F; 13,500 B.P. through 10,000 B.P., 12°F; 10,000 B.P., through 8700 B.P., 8°F. Precipitation seems to have been lower during cooler intervals than are present levels. Precipitation also seems to have increased over the last 6000 yrs.

Logs above the present tree line imply that summer temperatures have fluctuated above present values between 6000 B.P. and 1220 B.P. Tree-ring studies indicate that temperatures during the 200 yrs preceding 1940 were as much as 2°F cooler than present.

Ridler, R.H.

RELATIONSHIP OF MINERALIZATION TO STRATIGRAPHY IN THE ARCHEAN RANKIN INLET-ENNADAI BELT AS COMPARED WITH ANALAGOUS "GREENSTONE" BELTS OF THE SUPERIOR PROVINCE; Can. Mining J., v. 92, no. 4, p. 50-53, 74.

Highly differentiated volcano-sedimentary complexes within the Archean Rankin Inlet-Ennadai Belt in the Churchill Province bear a remarkable similarity to those in the Wawa-Abitibi Belt of the Superior Province. Thick, extensive mafic platforms are surmounted locally by intermediate to felsic domes. Volcanogenic chemical (exhalite) and clastic sediments mantle the domes and may blanket the mafic platforms for considerable distances. The sequence may be repeated three times.

Favourable lithic environments for gold include intermediate to felsic sills, stocks and volcanics, sulfide-rich exhalite and coarse basal sediments; for copper, zinc and silver, sulfide exhalite; for nickel, differentiated mafic sills; and for iron, both oxide and carbonate exhalite and iron formation of clastic derivation. As with the Wawa-Abitibi Belt, increasing age may favour Ni and simple Au mineralization while increasing youth may favour more complex polymetallic exhalite. Regional distribution patterns of exhalite facies indicate a basin and "shelf" configuration similar to that demonstrated for the Wawa-Abitibi Belt.

An initial exploration problem was the failure to distinguish between those gossans developed on interflow material of limited economic potential but widespread occurrence and those developed on the main exhalite zones of prime economic potential. Future problems will be encountered wherever superimposed Hudsonian orogenic effects transpose, disperse or obliterate Archean stratigraphic trends.

In spite of these difficulties, the overwhelming similarities of the complex geology of the two belts, the presence of numerous base and precious metal showings and abundant iron formation of diverse species, and the magnitude of the Rankin Inlet–Ennadai Belt inescapably lead to the conclusion that major ore-fields, similar in most respects to those in the Superior Province will reward the persistent application of modern exploration techniques and metallogenetic concepts.

Hutchinson, R.W., Ridler, R.H., and Suffel, G.G.

METALLOGENIC RELATIONSHIPS IN THE ABITIBI BELT, CANADA: A MODEL FOR ARCHEAN METALLOGENY; Can. Inst. Mining Met. Trans., v. LXXIV, p. 106-115, 1971.

Significant geological differences between the Archean and later eons suggest that the Archean is unique in representing primitive stages of crustal evolution of the earth. Archean metallogeny may also be unique. It is undoubtedly important, not only to Canada in view of the many mineral deposits in Archean rocks, but also scientifically because the primitive stages and processes of mineral deposit genesis must be recorded in these early rocks.

The important mineral deposits of the Archean in Canada include those of nickel (as well as asbestos), copper, zinc, silver, gold and iron, all of which occur in the apparently eugeosynclinal greenstone belts. Four major families are recognized: the Ni-Cu ores with mafic-ultramafic intrusions; the Cu-Zn-Ag-Au ores with mafic to felsic extrusive rocks; Fe- and Au-bearing ores with chemically deposited sedimentary rocks of probably exhalative origin; and iron-formations with rocks of the clastic sedimentary lithofacies. These four families of mineral deposits can be gradational in time and space with one another, as are their associated rocks. All originated within specific stratigraphic and tectonic environments in Archean rocks. The Ni-Cu deposits in mafic-ultramafic plutons may occur throughout widespread basal basaltic lava platforms. They may be connected through deposits of intermediate chemical and lithologic character to the pyritic Cu-Zn-Ag-Au ores in extrusive rocks, occurring in domal centers of felsic volcanism. Similarly, the latter deposits may be related through pyritic iron-formations to the Fe-Au deposits in the chemical sedimentary rocks, which were deposited in and near the felsic domes. These deposits, in turn, are transitional into the iron-formations occurring in argillites and greywackes that were deposited in mobile troughs flanking the felsic domes. Investigation of cation content, ratios and distribution within the various facies of iron-formation may prove useful in tracing these rocks toward centers of exhalative volcanism where concentrations of base or precious metals might occur.

It is crucial to investigate the conditions under which both host rocks and ores originated, in order to understand the aforementioned distributions of various mineral deposits in differing rock types. In general, how-

ever, these patterns result from the broad processes of supracrustal igneous activity and related sedimentation which dominated early Archean time. The building up and degradation of volcanic piles produced the primary, syngenetic types and distributions of rocks and mineral deposits outlined above. Later, secondary and epigenetic types, notably vein deposits of the precious metals, skarn deposits and rare-element pegmatites, may have been derived from the earlier syngenetic ones by metamorphism due to one or more later metamorphic, orogenic or intrusive events. These may be of early Archean, Kenoran or post-Archean age.

The primary associations of mineral deposits in Archean supracrustal rocks are very similar to those of the Initial and Early phases of the Bilibin metallogenic cycle for Phanerozoic orogenic belts. Differences are consistent with the great age of the Archean, which represents the earliest known and most immature stages of crustal evolution. Some secondary deposits, particularly those relatable to Kenoran orogeny, are comparable to those of the Middle phase of the Bilibin sequence. Significantly, those deposits typical of later, more mature phases of Bilibin's sequence are unrecognized or embryonic in the Archean, although they may be characteristic of Proterozoic metallogeny.

It is suggested that the Archean greenstone belts are synclinally preserved remnants of widely distributed strata formed from the primitive mantle by intrusive, extrusive and related exhalative activity, accompanied by erosion and sedimentation. These broad processes formed the Archean crust, depositing both rocks and mineral deposits as coeval products. Four broad families of deposits with their transitional relatives are recognizable, despite variations in diverse local conditions.

Suffel, G.G., Hutchinson, R.W., and Ridler, R.H.

METAMORPHISM OF MASSIVE SULPHIDES AT MANITOUWADGE, ONTARIO, CANADA; Soc. Mining Geol. Japan, Spec. Issue 3, p. 235-240 (1971) (Proc. IMA-IAGOD Meetings '70, IAGOD Vol.)

The massive sulphide ores of Manitouwadge, Ontario, have been regarded since their discovery in 1953 as selective epigenetic replacement bodies related to late Archaean (Kenoran or Algoman) orogeny and granite intrusion. Although this theory has been generally discarded in recent years for the numerous sulphide deposits of Northwestern Quebec and adjoining Ontario, published descriptions of the somewhat isolated Manitouwadge deposits show no change in viewpoint.

It is the purpose of this paper to present another possible interpretation. These orebodies may be highly metamorphosed stratiform deposits that owe their epigenetic features to deformation, remobilization and reactivation accompanying the well recognized regional metamorphism which altered the country rock to gneisses and schists of almandine-amphibolite facies.

Discussion will be largely confined to the Geco orebody for the sake of conciseness, although smaller bodies exist on the same general stratigraphic horizon to the west, mined by Willroy Mines and affiliates.

Rimsaite, J.

DTA, TGA, IR AND ISOTOPIC ANALYSES AND PROPERTIES OF PHLOGOPITE, BIOTITE, MUSCOVITE AND LEPIDOLITE IN TEMPERATURE RANGE OF METAMORPHIC REACTIONS; 3rd International Conference on Thermal Analysis, August 23-28, 1971, Davos, Switzerland, "Abstracts of Papers", p. V-10.

Relationships between oxidation, dehydration and temperature and the dehydration/oxidation effects on chemical, physical and structural properties of ten primary and secondary micas were studied on specimens heated in argon and in air at temperatures from 450°C to 1100°C. Chemical, optical, XRD, IR and isotopic analyses of argon were made on the original and on heated portions of the micas. Shape and sharpness of their DTA, TGA and IR curves depend on temperature differences between oxidation, dehydration, structural decomposition, crystallization of new anhydrous phases and proportions of the original and new amorphous and crystalline phases. The expansion of crystal lattice in heated muscovites and its contraction in the biotites and quantitites of retained, introduced and released atmospheric and radiogenic argon are correlated with the vacant anionic positions due to dehydration and their ferric iron contents. Examples of natural partly-dehydrated anatectic and metamorphic micas conclude the paper.

Rimsaite, J., and Lachance, G.R.

SPINEL-MICA PARAGENESIS IN THE THOMPSON NICKEL BELT, MANITOBA; Geol. Assoc. Can. - Mineral. Assoc. Can.; Ann. Meeting, Sudbury, May 1971; Abstr. Volume, p. 58, 1971.

Chromian spinels from the Thompson Nickel Belt range in composition from zincian chromian hercynite to zincian chromite. They are found in association with micas as inclusions in massive pyrrhotite-pentlandite ore, in narrow bands and segregations between the ore and biotite selvages, and in mica-sillimanite layers in the wall rocks adjacent to the massive sulphides. The chromian spinels have mottled appearance, some are zoned, and vary in colour from pale yellow through honey-brown to deep red. An electron probe microanalysis indicated the following relationships between the colour and their chemical composition: (1) the pale yellow variety contains the highest concentrations of alumina and zinc: $(Mg_{.05}Fe_{.55}Zn_{.4})(Al_{1.6}Cr_{.4})O_4$; it is rimmed by (2) the reddish spinel which is composed dominantly of chromite and contains minor ferric iron oxide: $(Mg_{.04}Fe_{.82}Zn_{.14})(Al_{.9}Cr_1Fe^{3+}_{.1})O_4$; and (3) the brown variety which has an intermediate chemical composition and occurs in intergrowths with the yellow and red spinels. The spinels contain about 0.1 per cent nickel and are closely associated with orange-brown biotite. The biotite encloses spinel or in turn is enclosed in the spinel. Selvages between the massive sulphides and silicate xenoliths consist mainly of reddish-brown biotite and minor greenish muscovite, and chlorite. The micas and chlorite genetically related to Ni and Cr mineralizations contain from ten to hundred times more Ni and Cr than these minerals from common rocks. The variations in chemical composition of the chromian spinels and of the micas can probably be used as indicators of associated base metals mineralization.

Farmer, V.C., Russell, J.D., McHardy, W.J., Newman, A.C.D., Ahlrichs, J.L., and Rimsaite, J.Y.H.

EVIDENCE FOR LOSS OF PROTONS AND OCTAHEDRAL IRON FROM OXIDIZED BIOTITES AND VERMICULITES; Mineral. Mag., v. 38, no. 294, p. 121-137, 1971.

Infra-red examination of a weathered biotite and of biotites that have been converted to vermiculites and subsequently oxidized, indicates that oxidation of octahedral ferrous ions to ferric ions is associated with a reversible conversion of hydroxyl ions to oxide ions. Subsequently, in high-iron biotites, there is an irreversible loss of ferric ions from the octahedral layer, resulting in an increased number of dioctahedral sites. Electron microscopy and X-ray diffraction indicate that ejected ferric ions form either amorphous interlayer oxides or, when bromine is used as an oxidant, a crystalline external phase of β-FeOOH. The high refractive index of some oxidized vermiculites is shown to be due largely to submicroscopic iron oxides.

Rose, E.R.

NOTES ON REMANENT MAGNETISM ASSOCIATED WITH SOME TITANIFEROUS DEPOSITS IN CANADA; Geol. Assoc. Can., Proc., v. 24, no. 2, p. 69-74, 1972.

Many strong positive aeromagnetic anomalies, in gabbroic phases of anorthositic rocks in Canada, are associated with occurrences of titaniferous magnetite (magnetite-ilmenite) and are attributed mainly to their large component of induced magnetism. A number of outstanding negative aeromagnetic anomalies, associated with ilmenite (ilmenite-hematite) deposits in anorthosite, are produced mainly by their strong component of reversed remanent magnetism. Reverse polarization is commonly found in rocks carrying ilmenite-hematite, magnetite-ilmenite, and other iron-titanium oxide intergrowths. The association of ilmenite-hematite and other iron-titanium oxide intergrowths is so persistent that these minerals and intergrowths should be suspected as causes of reverse polarization wherever it is found. Magnetite-ilmenite and ilmenite-hematite occurrences are commonly gradational and intermixed, and the resulting magnetic anomaly, if present, is due to an interplay of forces of induced and remanent magnetism, which may be positive or negative, and inclined in any direction. The orientation of magnetization in ilmenite-hematite magnetite-ilmenite and other intergrowths of iron-titanium oxide minerals of widely different Curie Points may not be reliable for palaeomagnetic deduction.

Valencia, M.J., and Roy, K.J.

CALCIUM CARBONATE AND GROSS SIZE ANALYSIS OF SURFACE SEDIMENTS, WESTERN EQUATORIAL PACIFIC; Geol. Soc. Am. Abstr. Prog., v. 4, no. 3, p. 252-253, 1972.

Forty free fall, trigger weight, and piston core tops from the Western Equatorial Pacific were separated into three size fractions (44,

44-246, >246 microns) and the calcium carbonate content of the total sample and of each fraction determined. Dilution due to subaerial volcanism from a westerly source prompted exclusion of some samples from the calcium carbonate and size-fraction profiles. The initial abrupt decrease in sediment calcium carbonate content is at 3500 meters whereas the compensation depth is at 5250 meters. Comparison of the results of previous investigations and examination of the present data prompts the assertion that under specified conditions, the effect of a calcium carbonate solution boundary may be discerned in plots of sediment calcium carbonate content versus depth. A strong positive correlation (0.92, $P < .001$) of the less than 44 microns fraction with depth suggests that anomalous values for this weight fraction may be useful in delineating displaced surface sediments in the region. The carbonate of the greater than 246 microns fraction is more resistant to solution below 3500 meters than the carbonate of the finer fractions.

Roy, K.J., and Smith, S.V.

SEDIMENTATION ASSOCIATED WITH REEF COMMUNITY CHANGES, OAHU, HAWAII; Geol. Soc. Am., Abstr. Prog., v. 3, no. 6, p. 409-410, 1972.

Short term increased production of sediment by a reef complex may be related to modification or decline of reef communities rather than increased biological production. Kaneohe Bay, Oahu, Hawaii is a location where increased deposition of calcium carbonate sediments is associated with apparent decreased skeletal production.

Kaneohe Bay is about 8 miles long and 4 miles wide and contains a barrier reef-lagoon-fringing reef complex. The lagoon is up to 55 feet deep and is floored by a muddy fecal pellet sand. Deposition of sediment in the lagoon has increased from nearly zero in the 45 years prior to 1927 to 5.4 feet in the 42 years between 1927 and 1969. Part of the increase is due to increased influx of terrigenous material. However, there was also a major increase in deposition of reef derived material.

In association with a general change in bay ecology, coral abundance has decreased in the past 20 years. Although corals are the major $CaCO_3$ producers in the Bay, only 40 per cent of the $CaCO_3$ in the lagoon sediment is aragonite. Thus a major source of aragonite, as well as calcite is needed to satisfy the post-1927 depositional requirements. Active erosion, both biological and mechanical, of the extensive cover of encrusting coralline algae, as well as the cemented reef framework, could provide the necessary material.

It is inferred that subaqueous erosion has been accelerated as a result of the biologic changes in the bay. By analogy, changes in ancient reef communities may be indicated by increased $CaCO_3$ content in surrounding shales. Subaerial exposure of the reefs or increased organic productivity is not required.

Roy, K.J., and Smith, S.V.

SEDIMENTATION AND CORAL REEF DEVELOPMENT IN TURBID WATER: FANNING LAGOON; Pac. Sci., v. XXV, no. 2, 1971.

Lack of light and excessive sediment deposition rates are factors limiting coral reef development. The presence of very turbid water and muddy bottom does not mean, however, that coral growth is prohibited. Fanning Lagoon has a turbid water area (visibility, 2 m) and a clear water area (visibility, 10 to 15 m). Both areas have a muddy bottom. Because of the shallow depth and the light-scattering effect of the suspended $CaCO_3$, relative light intensity at the bottom is greater than 5 percent. The cleaning mechanism of the corals is sufficient to handle the deposition of sediment. Live corals cover 62 per cent of the clear-water area and 31 percent of the turbid. Reefs in the turbid water are ecologically different from the ones in clear water, but they are still living reefs. Ramose corals make up 55 percent of the individuals in the turbid water and only 10 per cent of those in the clear water. This difference is reflected in the structure of the reefs; those in clear water are massive and steep-sided, while those in the turbid water have gentler slopes and are more open with sediment infill. Fanning Lagoon is an example of penecontemporaneous formation of reef and intervening muddy sediment with bathymetric relief never more than 8 m.

Smith, S.V., Roy, K.J., Schiesser, H.G., Shepherd, G.L., and Chave, K.E.

FLUX OF SUSPENDED CALCIUM CARBONATE ($CaCO_3$), FANNING ISLAND LAGOON; Pac. Sci., v. XXV, no. 2, 1971.

A plume of turbid, $CaCO_3$-laden water (0.24 mg/liter) is expelled from English Harbor, Fanning Atoll, on outgoing tides. On incoming tides, the concentration is 0.36 mg $CaCO_3$/liter. At the two other passes of the atoll, incoming $CaCO_3$ concentrations also are higher than outgoing concentrations. Lagoon waters contain 1 mg $CaCO_3$/liter in the clear central portion of the lagoon and 4 mg $CaCO_3$/liter elsewhere. Offshore concentrations out of the plume area are 0.03 mg $CaCO_3$/liter. The lagoon and plume $CaCO_3$ material is reef-derived detritus (aragonite and high-Mg calcite). Offshore $CaCO_3$ particles are primarily coccoliths (low-Mg calcite).

During a 24-hour survey 10 tons of suspended $CaCO_3$ were transported into the lagoon. It is likely that the English Harbour plume represents little or no sediment loss from the lagoon.

The plume debris is interpreted to be material produced on the outside fringing reefs, sucked into the lagoon on incoming tides, and subsequently expelled. Production of $CaCO_3$ in the lagoon may be filling the lagoon faster than sea level is rising.

Rutter, N.W.

ALPINE GLACIAL FEATURES, CENTRAL PERUVIAN ANDEAN MOUNTAINS, REVUE "PHOTO INTERPRETATION"; No. 3, Editions Technip, Paris, 1971.

The location of the area illustrated is in the central Peruvian Andean Mountains lying within south latitude 13°00' and 13°05' and west longi-

tude 71°01' and 71°06', near the city of Ayacucho which is about 350 km southeast of Lima. The region consists of rugged mountains with the highest peaks rising over 4,300 m and a local relief of as much as 800 m.

The airphotographs illustrate the contrast between glaciated and unglaciated surfaces. The outstanding features present are series of arcuate lateral, recessional and terminal moraines seen on most glaciated surfaces. These extremely intricate moraine ridges, often apparent only as strings of large glacial erratics, are common throughout the central Peruvian Andes. It is possible to observe ridges representing at least 14 ice-frontal positions in the major valley near the top left part of the central photograph even though many have been eroded and dissected. Moraine ridges, on the average, have a local relief in the order of 2 or 3 m and a width of 7 or 8 m. They consist invariably of unsorted till composed mostly of sand, with lesser amounts of silt and some clay. The till contains about 60 to 70% subrounded to subangular inclusions (>4 mm in diameter) consisting mostly of volcanic rocks along with some metamorphic, hypabyssal and plutonic rocks. Most inclusions show little or no weathering, although some are highly weathered. Other prominent glacial features are arêtes, cols, horns, cirques and U-shaped valleys with distinct margins of former glacier limits. The lowest elevation that glaciers extended to was about 3,750 m.

The geomorphology of the moraines and composition (mostly till and very little ice-contact stratified drift) suggest that the moraine ridges represent equilibrium phases during the maximum extent of ice as well as during recession. Moraines do not appear to have been formed by ablation of stagnant ice.

In the lower parts of the valleys and between morainal ridges, the thickness of glacial drift (mainly till) varies, but generally is less than 5 m thick. The drift cover is thin and patchy on the steep slopes and much of it is reworked and masked by colluvium.

The moraines appear to represent one major glaciation. In a comparable area nearby, relative ages of moraines were determined by the thickness of weathering rinds in andesite and thickness of soil horizons. It was found that weathering rinds averaged about .17 cm and soil horizon thicknesses (A and B horizons combined) about 55 cm both in the youngest moraines located in the upper part of the valley and oldest moraines located near the maximum extent of ice. It is difficult to assign an absolute time of the glaciation but it is most likely Würm because of the fresh appearance of the moraines, the shallow soil development and the low degree of rock weathering.

The present climate of the area is cool with little seasonal variation in temperature. Daily variations are between 0° and 20°C. Precipitation, mostly in the form of rain, averages about 60 cm per year. The region is mainly in the tundra zone and the vegetation consists mostly of grasses, sedges and moss. A zone of scrub forest can be observed in the major valleys below about 4,000 m. Agriculture is very limited in this inhospitable area. A few potato plots can be observed as dark patches in the lower parts of valleys at higher elevations. In the lower parts of the three deepest valleys near the margins of the photos stone fences enclose small plots producing mainly wheat.

Sangster, D.F.

METALLOGENESIS OF SOME CANADIAN LEAD-ZINC DEPOSITS IN CARBONATE ROCKS; Geol. Assoc. Can., Proc., v. 22, p. 27-36, 1970.

Three main types of lead-zinc deposits in carbonate rocks have been recognized in Canada. Two may be termed conformable. One of these occurs peripheral to or between undeformed sedimentary basins in clean, massive or coarse-bedded, vuggy, sometimes reefal, dolomite and consists of massive to disseminated sulphides. Pine Point is of this type. In contrast, the other occurs in intensely deformed, dark, well-bedded dolomite intruded by rocks of granitic to intermediate composition. The sulphide bodies are layered and may be deformed and/or thermally metamorphosed. Remac mine in the Kootenay Arc is an example of this type. Several lines of evidence suggest that the two conformable types are similar in origin but not in time of emplacement.

The third, or non-conformable, type are typically Pb(Zn)-Ag-barite veins. Good examples are found in the marble belt of the southern Grenville province, where evidence suggests that they are related to the Ottawa Valley graben structure of possible Cretaceous age and thus have no close relationship to the rocks that contain them.

Sangster, D.F.

GEOLOGICAL SIGNIFICANCE OF STRATABOUND SULPHIDE DEPOSITS; Geol. Assoc. Can., Proc., v. 23, p. 69-72, 1971.

Recognition of the coeval relationship between many stratabound sulphide deposits and their host rocks is having the effect of bringing the study of these orebodies into the mainstream of geological advancements. Examples are presented to illustrate how several earth science disciplines, other than economic geology, could find challenge in, and contribute to, a study of stratabound sulphide ores. Conversely, these deposits contain valuable data which bear upon such geological concepts as global geochemistry, Earth history, primordial atmosphere, basin analysis, and petrochemistry.

Sangster, D.F.

SULPHUR ISOTOPES, STRATABOUND SULPHIDE DEPOSITS, AND ANCIENT SEAS; Soc. Mining Geol. Japan, Spec. Issue 3, p. 295-299 (1971) (Proc. IMA-IAGOD Meetings '70, IAGOD Vol.).

Data from approximately 100 orebodies are presented to demonstrate that a parallel variation exists between the isotopic composition of sulphur in stratabound sulphide ores and coeval seas throughout geologic time.

Sulphide ore minerals of both "sedimentary type" and "volcanic type" of deposits exhibit similar sulphur isotopic characteristics. Fractionation of ore minerals, relative to coeval seawater sulphate, closely agrees in range, sense, and average magnitude with that produced by bacterial action. These data strongly suggest that most of the sulphide sulphur in stratabound ores was bacterially-produced from seawater sulphate.

Sangster, D.F., and Liberty, B.A.

SPHALERITE CONCRETIONS FROM BRUCE PENINSULA, SOUTHERN ONTARIO, CANADA; Econ. Geol., v. 66, p. 1145-1152, 1971.

Disc- and spherical-shaped sphalerite concretions, containing variable amounts of carbonate, occur in thin-bedded Silurian dolomite of southern Ontario. Seven of these range from 27 to 92 weight percent ZnS and trace element analyses show that the sphalerite is relatively pure. Sulfur isotope compositions of 15 specimens ranged from -1.48 to -5.41 $\delta\ ^{34}S‰$ with an average of -3.05‰. The presence of possible gypsum molds in the concretions, the isotopic composition of sulfur, the high zinc and hydrocarbon content of the host dolomite, and the broader geological environment of their occurrence, together suggest a biogenic-diagenetic process for the formation of the concretions.

Sen Gupta, J.G.

THE DETERMINATION OF NOBLE AND BASE METALS IN OSMIRIDIUM, NATIVE PLATINUM AND SPERRYLITE BY ATOMIC ABSORPTION SPECTROPHOTOMETRY; Anal. Chim. Acta, v. 58, p. 23-37, 1972.

Atomic absorption spectrophotometric methods for determining the noble and base metals in osmiridium, native platinum and sperrylite have been developed and applied to the analysis of some naturally occurring samples. The sample is decomposed by dry chlorination at 700° in the presence of sodium chloride, or by treatment with aqua regia (native platinum) or Br_2-KBr (sperrylite) followed by dry chlorination of the insoluble residue. Osmium and ruthenium are separated by distillation with perchloric acid and collected in hydrobromic acid. From different aliquots the noble metals are determined in the presence of 0.5% Cu-0.5% Cd buffer and the base metals in the presence of 1% lanthanum or strontium buffer.

Schwarz, E.J.

MAGNETIC PHASE RELATIONS OF PYRRHOTITE; IAGA Bull. 9, Programme IUGG meeting, Moscow, 1971.

Natural pyrrhotite often occurs as an intergrowth of chemically distinct phases. A thermomagnetic method was developed to quantitatively determine the compositions and their relative abundance. The evidence from work on natural and synthetic pyrrhotites is that continuous solid solution does not exist in the entire range $Fe_{1-x}S$ ($0 \leq x \leq 0.13$) but that only pyrrhotites of rational Fe/S ratios (e.g. Fe_7S_8, Fe_9S_{10}) tend to occur. Adaption of Bertaut's vacancy ordering scheme for Fe_7S_8 to less Fe deficient phases leads to different stacking orders of vacancy containing and filled cation basal layers. The advantage of such vacancy schemes is that the usually made assumption of disordered vacancies (causing antiferromagnetism) below the γ transition (appearance of ferrimagnetism) is not needed.

Schwarz, E.J., Symons, D.T.A., and Christie, K.W.

VARIATION IN LOCAL MAGNETIC FIELD PARAMETERS DURING COOLING OF THE SUDBURY NORITE; IAGA Bull. 9, Programme IUGG meeting, Moscow, 1971.

About 200 oriented cores were collected from two continuous outcrops (each about 100 m long) of norite. Each core yielded two specimens for alternating field demagnetization in stages and two specimens for thermal demagnetization in stages. The preliminary results show well-defined trends in both the variation of low-field susceptibility and in the parameters of the stable remanence. The latter may yield information on the time variation of the local direction and intensity of the cooling field 1700 m.y. ago which may be analysed in terms of dipole and non-dipole components of the paleomagnetic field as well as on some geological aspects of the cooling history of the norite.

Schwarz, E.J., and Harris, D.C.

PHASES IN NATURAL PYRRHOTITE AND THE EFFECT OF HEATING ON THEIR MAGNETIC PROPERTIES AND COMPOSITION; J. Geomagn. Geoelec., v. 22, no. 4, p. 463-470, 1970.

The thermomagnetic records of natural pyrrhotite were interpreted on the basis of two phases differing in magnetic properties. The chemical composition of these phases as deduced from these records agrees with the microprobe results obtained for suitable unheated specimens. The thermomagnetic method requires heating the specimens to about 310°C, but the microprobe results show that loss of sulphur is confined to the surface of the specimens when heated in argon at the rate of 5°C/minute. The results obtained with both methods of analysis indicate homogenization of the specimens at 400°C which may be due at least in part to appreciable loss of sulphur. The thermomagnetic method has the advantage that finely dispersed mixtures of the phases can be analysed and that their relative abundance can be easily estimated.

Vaughan, D.J., Schwarz, E.J., and Owens, D.R.

PYRRHOTITES FROM THE STRATHCONA MINE, SUDBURY, CANADA: A THERMOMAGNETIC AND MINERALOGICAL STUDY; Econ. Geol., v. 66, p. 1131-1144, 1971.

Pyrrhotites collected from sulfide concentrations in the irruptive and the underlying gneiss complex at the Strathcona Mine, Sudbury, were studied microscopically, by electron microprobe, thermomagnetic, X-ray, DTA and Mössbauer methods. The results show that two pyrrhotite types occur in this section through the orebody. The first is of composition $(Fe, Ni)_7S_8$ with Ni ≈ 0.35-0.50 wt. % and is ferrimagnetic up to 300-305°C. X-ray powder data are in good agreement with those for "monoclinic" pyrrhotite with a 2A, 4C supercell. the second pyrrhotite is of composition $(Fe, Ni)_9S_{10}$ with Ni ≈ 0.68-1.01 wt. % and is ferrimagnetic between ~ 200 and 250°C. X-ray powder data are in agreement with those for so-called "hexagonal"

pyrrhotite with a 2A, 5C supercell. In the upper part of the section large amounts of both types of pyrrhotite occur intimately intergrown, but near the base of the irruptive there is an abrupt change to single-phase $(Fe,Ni)_7S_8$. Near the base of the orebody both types again become abundant. Electron microprobe analysis of the two pyrrhotite types and the associated pentlandite show greater concentrations of nickel in the pyrrhotites (of high susceptibility) and pentlandite towards the center of the section, with a concomitant decrease in the cobalt content of the pentlandite. The "hexagonal" pyrrhotite consistently shows an enrichment in residual nickel relative to the "monoclinic" type and is more readily etched by HI. Further studies of the two separate pyrrhotite types by Mössbauer spectroscopy and differential thermal analysis, together with the magnetic and X-ray data, suggest that each represents different, but definite, layer-order schemes of vacancies on the iron sites in the (001) planes. The Bertaut model for $(Fe,Ni)_7S_8$ with the vacancies ordered in alternate iron atom planes parallel to (001), is consistent with these data and for $(Fe,Ni)_9S_{10}$ a model with single and double filled planes alternating with those containing vacancies is proposed. Study of synthetic pyrrhotites containing low concentrations of nickel suggest that the nickel is evenly distributed over the magnetic sublattices in both types. This study suggests that variation in the original bulk composition of a sulfide melt is expressed as variation in the proportions of these essentially stoichiometric pyrrhotites and other co-existing sulfides.

Schwarz, E.J., and Winer, A.A.

MAGNETIC PROPERTIES OF ASBESTOS, WITH SPECIAL REFERENCE TO THE DETERMINATION OF ABSOLUTE MAGNETITE CONTENTS; Can. Inst. Mining Met., Trans., v. LXXIV, p. 259-263, 1971.

Absolute magnetite contents were determined for asbestos specimens in various stages of milling by using a Faraday-type thermomagnetic balance. Comparison of these results with magnetic ratings (MR) supplied by the mining companies cooperating in this study reveals strong scatter. The main cause of this scatter is thought to be that the MR values were obtained in magnetic fields well below the saturating field of magnetite (5,000 oe). However, only the saturation moment is an intrinsic property and consequently must be used for the purpose of obtaining reliable estimates of the magnetite content. Curie points indicate that virtually pure magnetite and possibly Ni_3Fe is present in all samples, and another phase, probably (Cr, Al) magnetite, is present in a few samples.

The susceptibility in fields stronger than 5,000 oe is positive and falls in the normal paramagnetic range, whereas synthetic chrysotile exhibits weak diamagnetism. This suggests that, as a general rule, the least adulterated natural chrysotile concurs with the samples showing the smallest positive susceptibility above 5,000 oe. The magnetite appears to increase in quantity with a decrease in fibre length and to be somewhat more uniform in distribution for samples showing substantial fiberization (opening of the fibres).

Shilts, W.W.

TILL STUDIES AND THEIR APPLICATION TO REGIONAL DRIFT PROSPECTING; Can. Mining J., v. 92, no. 4, p. 45-50, 1971.

Skinner, R.G.

A LATE GLACIAL SHORT-LIVED SALINE UNDERFLOW IN SOUTHERN JAMES BAY, CANADA; Geol. Soc. Am., Abstr. Prog., v. 4, no. 1, p. 45.

During retreat of the last ice sheet in the James Bay lowlands, glacier ice was grounded in Hudson Bay between a lake to the south and marine water to the north. Eventually this ice barrier was breached and the Tyrrell Sea replaced the lake. The sediments representing this sequence include from bottom to top: glacio-lacustrine sand and gravel, overlain by bluish-grey silt-clay rhythmites or varves, a marine bluish-grey clay-pebble gravel with reddish-brown zones in it (particularly at the top), on which rest patches of unsorted sediment of probable ice-rafted origin, overlain by marine clay, silt and occasionally coarse beach facies. The clay-pebble gravel is a useful marker bed separating the lacustrine from the marine part of the section.

The sequence, varves to clay-pebble-gravel to clay, depicts a change in bottom velocity from low to high to low. This is believed to have been caused by a saline density underflow released when ice between sea and lake finally broke. Apparently this inferred underflow produced currents strong enough to erode the varves and transport pebble-sized clay clasts, producing a clay-pebble gravel.

Taylor, G.C.

THE INFLUENCE OF PRE-LARAMIDE TECTONICS ON ROCKY MOUNTAIN STRUCTURES; Geol. Assoc. Can., Cordilleran Mtg., Feb. 1972, Abstr. Prog.

The present spectacular topography resulting from the Laramide orogeny in the Rocky Mountains has tended to allow relegation of other, earlier deformations of the same rocks to a very minor role in theories of the tectonic evolution of the chain. Not only is this misleading, but it results in an incomplete understanding of the Laramide orogeny itself.

Perhaps nowhere else is the evidence of earlier tectonism as well displayed as in the northern Rocky Mountains. Studies there have outlined a complex sequence of Pre-Laramide tectonic events. The effect of these early structures on the development of Laramide structures has resulted in significant modifications of earlier theories on the tectonic evolution of that part of the Rocky Mountains. That these new concepts can also be applied to the southern Rockies should also be investigated.

The oldest rocks exposed in the northern Rockies are of probable Helikian age. Large normal, reverse, and thrust faults affecting these strata, and that pre-date Proterozoic dyke intrusion, have been recognized. A later Proterozoic, probable transcurrent fault, separates the Hadrynian succession from the Helikian rocks. Early Cambrian strata as well record very large (+7,000') normal faults that were active at the time of deposition. Subsequently Early and Middle Ordovician strata were also strongly deformed prior to Silurian time. These intensely and repeatedly deformed successions constitute a pseudo-basement underlying a miogeosynclinal succession (analogous to the southern Rocky Mountain miogeosynclinal succession) both of which were similarly deformed during the Laramide orogeny.

Two major conditions that modify previous theories of Laramide tectonism are apparent: first, as the result of previous deformations, the pseudo-basement has had its sedimentary layering so deformed that it no longer existed as a single, uniformly west-dipping mechanical element of anisotropy in the rock mass; and it follows that the sedimentary-crystalline rock interface was no longer a relatively planar west-dipping surface along which subsequent decollement could be expected. Second, although the later miogeosynclinal succession did detach from the pseudo-basement and deform by thrusting, the pseudo-basement itself was also deformed during the Laramide orogeny. Were the level of exposure in the northern Rockies such that the Pre-Silurian strata were not exposed, the structures would be exactly analogous to those of the southern Rockies requiring only an interpreted imbricate zone to "fill the Hole" to basement and thus satisfy the model of "an intricate array of interleaved thrust faults detached from, and overlying an undisturbed passive crystalline basement".

Taylor, G.C.

STRUCTURAL STYLE OF THE NORTHERN CANADIAN ROCKIES; Geol. Soc. Am., Abstr. Prog., v. 3, no. 6, p. 416, 1971.

The structural style of the northern Canadian Rockies differs radically from the model expounded for our southern Rockies. The total amount of shortening appears to be significantly less. Folding and faulting seem to have been concurrent with as much supra-crustal shortening attributable to the former as the latter. This different structural response can be directly attributed to a different stratigraphic column. Unlike the area to the south the stratigraphic column is punctuated by angular unconformities and, has a greater diversity of lithologies. This has resulted in the segmenting of the column into distinct packets of rock, separated by décollements, that have deformed internally and disharmonically with respect to vertically adjacent packets.

Five packets are recognized on the basis of structural style. The lowest observed is comprised of Proterozoic to Ordovician strata and includes three major angular unconformities. As such the effect of bedding as a thru-going dominant anisotropic element is largely negated by the complexity of these large scale pre-Laramide structures. Typical deformation of this packet has produced very large asymmetric folds with their steep east limb commonly broken by steep reverse faults. Without postulating a "never-seen" décollement, the possibility of crystalline basement being involved in these structures must be entertained.

The overlying packet consists of a blanket of carbonates of Silurian to middle Devonian age, that exhibits, on a reduced scale, the classical style of thrust faults of the Southern Rockies. This packet can be demonstrated to be detached from its basement of older strata, and apparently "floated" and deformed concurrently but disharmonically with its pseudo-basement.

The carbonate packet is separated by a major décollement from the third element consisting of fine clastics of Devonian through Permian age. Folding is the predominant style of deformation of this packet and it is strongly disharmonic relative to the underlying structure. The occurrence of a thick, massive carbonate member within the eastern sector of this packet has produced large box folds.

Triassic Grayling shales provide the décollement separating the fourth packet of Triassic through Lower Cretaceous sediments. The relatively thick and competent Liard sandstone is the determinant mechanical element and the resultant concentric folds, en echelon, characterize this level of the structure.

The fifth packet comprises predominantly late Cretaceous sediments and is preserved only along the eastern margin of the deformed belt. Very large, open, gentle folds characterize this portion of the column.

No direct continuum of all the structural types can be observed vertically, but the amount of deformation in vertically adjacent packets can be equalled despite the individually divergent styles of each packet.

Tiffin, D.L., Cameron, B.E.B., and Murray, J.W.

TECTONICS AND DEPOSITIONAL HISTORY OF THE CONTINENTAL MARGIN OFF VANCOUVER ISLAND, BRITISH COLUMBIA; Can. J. Earth Sci., v. 9, p. 280-296, 1972.

Sampling and seismic profiling in the Tofino Basin west of Vancouver Island show there is a thick sequence of Tertiary rocks ranging in age from late Eocene to Pliocene. The rocks are mainly mudstones containing abundant foraminifera indicating a bathyal depositional environment throughout most of the Tertiary. Subsequent uplift has exposed the deep water sediments on the shelf over much of the area. Eocene-Oligocene sediments occur in a belt along the inner shelf, while Miocene and Pliocene rocks lie seaward of this. Pliocene rocks form a regressive sequence overlapping the older Tertiary, with the greatest thickness in the south.

At least two major periods of deformation resulted in faulting, folding, and diapirism on the continental shelf. Deformational patterns show a marked change from north to south. North of Brooks Peninsula sediments are undeformed by folding but are truncated by faulting along the steep continental slope. The Kyuquot Uplift south of Brooks Peninsula exposes Eocene-Oligocene sediments across the shelf. Farther south Mio-Pliocene sediments unconformably overlie the uplift. Folding increases southward culminating in an area of diapirism off Nootka Sound. Elongate diapirs trend parallel or subparallel to the coastline.

Tectonic features on the shelf and slope appear to be related to present and earlier configurations of nearby offshore spreading centers, plates, and transform faults. Crustal plate movements may have been responsible for the observed shelf and slope deformations.

Srivastava, S.P., Barrett, D.L., Keen, C.E., Manchester, K.S., Shih, K.G., Tiffin, D.L., Chase, R.L., Thomlinson, A.G., Davis, E.E., and Lister, C.R.B.

PRELIMINARY ANALYSIS OF GEOPHYSICAL MEASUREMENTS NORTH OF JUAN DE FUCA RIDGE; Can. J. Earth Sci., v. 8, p. 1265-1281, 1971.

Preliminary analyses of gravity, magnetic, seismic reflection and refraction, dredging, and heat flow measurements off Queen Charlotte Islands

and Vancouver Island are presented. Seismic reflection and gravity measurements show the presence of a sedimentary basin at the foot of the continental slope in which the sediments are progressively more intensely deformed from north to south, indicating the interactions between the lithospheric plates. Heat flow values in the northern part of Explorer Ridge, and recovery of fresh basalts with little mineral coating in this region suggest that Explorer Ridge is a presently active spreading segment of East Pacific Rise. Seismic refraction results in the deep ocean basin west of Queen Charlotte Islands show a marked anisotropic mantle P wave velocity, the direction of maximum velocity being 107° east of north and the maximum change in velocity being about 0.6 km/s.

Tiffin, D.L., Murray, J.W., Mayers, I.R., and Garrison, R.E.

STRUCTURE AND ORIGIN OF FORESLOPE HILLS, FRASER DELTA, BRITISH COLUMBIA; Bull. Can. Petrol. Geol., v. 19, no. 3, p. 589-600, 1971.

Several continuous seismic profiles across the Fraser River delta, British Columbia, provide insight into the internal structure and possible origin of foreslope hills similar to those found on other major deltas. The continuity and wave-like progression of the structures suggest that these hills are the result of downslope movement of a large mass of sediment. It is estimated that the Fraser delta slump deposits are at least 200 years old.

Tipper, H.W.

MULTIPLE GLACIATION IN CENTRAL BRITISH COLUMBIA; Can. J. Earth Sci., v. 8, no. 7, p. 743-752, 1971.

Tozer, E.T.

ONE, TWO, OR THREE CONNECTING LINKS BETWEEN TRIASSIC AND JURASSIC AMMONOIDS?; Nature Friday, v. 232, no. 5312, p. 565-566, 1971.

Tozer, E.T.

TRIASSIC TIME AND AMMONOIDS: PROBLEMS AND PROPOSALS; Can. J. Earth Sci., v. 8, no. 8, p. 989-1031, 1971.

Klapper, G., Sandberg, C.A., Collinson, C., Huddle, J.W., Orr, R.W., Rickard, L.V., Schumacher, D., Seddon, G., and Uyeno, T.T.

NORTH AMERICAN DEVONIAN CONODONT BIOSTRATIGRAPHY; Geol. Soc. Am., Mem. 127, 1971.

The Lower Devonian of Nevada provides a reference sequence of nine conodont faunas, five of which are also at Royal Creek, Yukon Territory. The first appearance of Icriodus woschmidti is comparable to that in the lower Gedinnian in Europe; the Polygnathus dehiscens-P. foveolatus lineage

correlates with the Emsian. Directly associated graptolite and brachiopod zones in Nevada date the intervening conodont succession as upper Gedinnian and Siegenian.

Five faunas characterize the lower Middle Devonian (Eifelian) in New York; at least two of the lower three are present in the Illinois Basin. Illinois Basin faunas correlative to the upper two New York faunas (Seneca and Cherry Valley) have Icriodus angustus, which is absent in New York, but lack Polygnathus kockelianus, which marks the top of the New York Eifelian.

Three faunas subdivide the upper Middle Devonian (Givetian) in the Illinois Basin; the lower two occur in New York and Michigan.

The Middle Devonian-Upper Devonian boundary possibly falls at the base of or within beds carrying the Spathognathodus insitus fauna. Alberta and Iowa sequences from the Lower Polygnathus asymmetricus through Upper Palmatolepis gigas Zones closely correspond to the lower Upper Devonian in Germany. An Iowa section yields the standard lower Famennian zonal succession (Middle Palmatolepis triangularis through Upper Palmatolepis quadrantinodosa Zones). Higher Devonian faunas, in the western and central United States, are assigned with difficulty to the Scaphignathus velifer, Upper Polygnathus styriacus, and Spathognathodus costatus Zones. The faunal sequence of the S. costatus Zone differs significantly from that in Germany.

Yorath, C.J., and Parker, E.R.

MESOZOIC AND CENOZOIC HISTORY OF THE GRAND BANKS OF NEWFOUNDLAND: A DISCUSSION; Can. J. Earth Sci., v. 8, no. 12, p. 1606-1607, 1971.