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8. The Orgueil magnetite and St. Séverin samples were irradiated together with several lunar and terrestrial samples as part of an irradiation designated "Vallecitos 4." The St. Séverin sample was included to serve as a monitor of known I-Xe age (*2*).
9. The complete isotope ratios for all temperatures of both samples are too bulky to include in this report. The data have been tabulated and are available on request from the authors. A curious feature of the rest of the data is an excess of the heavy isotopes of xenon, above that of AVCC. The summed ^{134}Xe/^{132}Xe and ^{136}Xe/^{132}Xe ratios are 0.3902 and 0.3319, respectively, with a total ^{132}Xe content of 1.51×10^{-9} cm^3/g (STP). Neutron induced fission can only account for $\lesssim 30$ percent of this excess, based on a limit for uranium of < 10 parts per billion by Krähenbühl *et al.* (U. Krähenbühl, J. W. Morgan, R. Ganapathy, E. Anders, *Geochim. Cosmochim. Acta*, in press). The remainder of the excess could be accounted for either by a very high Pu/U ratio of $\geqq 0.06$ or by the presence of fission xenon of the carbonaceous chondrite type [M. W. Rowe, *Geochim. Cosmochim. Acta* **32**, 1317 (1968)]. Unfortunately, the anomalies are too small to test these two possibilities.
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14. Jeffery and Anders (*6*) estimated an ^{129}I/^{127}I ratio of 1.3×10^{-4} (± a factor of 2), based on the Br content of the magnetite, 0.96 part per million, and an assumed I/Br ratio equal to the cosmic value. Although fortuitously close to our ratio of $(1.4 \pm 0.13) \times 10^{-4}$, it is not really comparable to it, because it refers to total rather than correlated, high-temperature iodine. Our data yield a markedly lower "total" ^{129}I/^{127}I, 0.41×10^{-4}, but the discrepancy may in part reflect differences in separation procedure [NaOH in (*6*), LiCl in this work].
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22. A possible complication arises from the fact that there are two kinds of magnetite in Orgueil (*23*): submicrometer-sized grains intergrown with silicate and spheres or platelets 5 to 20 μm in diameter associated mainly with $MgSO_4$ and dolomite veins. The fine-grained material most likely formed in the nebula by reaction 2, whereas part or all of the coarse-grained material may have formed in the parent body, during an episode involving liquid water (*24*). Owing to the high water-solubility of iodides, it seems likely that the presence of an aqueous phase would cause less iodine to enter the magnetite lattice. Consequently, one would expect the second-generation magnetite to contribute only a minor part of the total ^{129}Xe, and hence have only a minor effect on the I-Xe age.
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26. We are tacitly assuming that metamorphism in Karoonda was severe enough to reset the I-Xe clock. In support of this assumption we note that Karoonda is more strongly recrystallized than the L4 chondrite Bjurböle, which is used as a reference meteorite in I-Xe dating; in fact, W. R. Van Schmus [in *Meteorite Research*, P. Millman, Ed. (Reidel, Dordrecht, 1969), pp. 480–491] suggested that Karoonda should perhaps be reclassified to C5.
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* Present address: Department of Chemistry, Douglass College, New Brunswick, New Jersey 08903.

† Present address: Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637.

5 January 1973; revised 7 February 1973 ■

Glaciers and Nutrients in Arctic Seas

Abstract. *Significantly higher concentrations of nitrate and silicate were found in glaciated South Cape Fiord than in unglaciated Grise Fiord, in the Canadian Arctic, or in adjacent Jones Sound. No significant differences in phosphate concentrations were found. Glacial activity apparently enriches the concentrations of those nutrients most critically limiting for arctic phytoplankton requirements.*

The effects of active, moving glaciers discharging into the sea on the nutrient content of adjacent waters have been the subject of some limited speculation. Vibe (*1*), for example, discussing conditions in northwest Greenland, remarked " . . . I hold the view that the glaciers far surpass precipitation as an erosive factor in procuring the inorganic material . . . which renders all organic life possible." Similarly, Sverdrup ". . . suggested that Antarctic waters should also receive much dispersed silica formed by comminution of rock beneath the very large glaciers of the Antarctic continent" (*2*). Hartley and Dunbar (*3*) discussed upwelling and enriching hydrodynamic processes associated with "brown zones" adjacent to glaciers terminating in the sea.

The hypothesis that active coastal glaciers enrich nutrient concentrations in the sea was tested in May 1969 in two of the numerous fiords that indent the southern shore (latitude 76°30′N) of Ellesmere Island, Northwest Territories, Canada. Glaciated and unglaciated fiords provide experimental and control areas, respectively, in which hypothetical effects of glaciation may be isolated and examined without undue external dilution, which might obscure glacial influence. Grise Fiord, the control area, extends inland approximately 38 km and does not have any glaciers reaching its shores. South Cape Fiord, the experimental area, is approximately 25 km long and has three glaciers reaching its shores (see cover photograph). The largest of these, unnamed, is approximately 32 km long and about 3.2 km wide where it reaches the fiord. This glacier evidently is active, calving small icebergs into South Cape Fiord. The cover photograph shows one such berg recently calved from the glacier front. In May 1969, at least 15 icebergs were frozen into the fiord.

At the time of this survey, air temperatures were in the range of −15° to −1°C and the entire area was snow-covered with no signs of spring thaw or melt. There were no effects on the sea of runoff from the land. Throughout the area of this study, Jones Sound and the adjacent waters were completely covered with intact, snow-covered sea ice averaging 0.75 to 1.0 m in thickness.

Grise Fiord has a maximum depth of about 365 m inside a sill depth of about 135 m. South Cape Fiord appears to be quite shallow in comparison. Soundings at three stations showed depths of 87, 67, and 77 m. Jones Sound is 500 to 600 m deep in the area of our stations.

Geologically, the two fiords are similar (*4*). Cambrian, Ordovician, and Silurian dolomites, limestones, and sandstones surround both fiords, except just at the mouth of Grise Fiord, where granitic "quartz-feldspar-biotite gneiss" is exposed (*4*). The glaciers in South Cape Fiord lie in the same dolomite and limestone beds that surround the two fiords.

Determinations (*5*) of the mineral nitrogen (NH_4^+ and $NO_2^- + NO_3^-$) contents of rock samples (*5*) from Grise Fiord and South Cape Fiord are in agreement with the majority of values (that is, less than 2.5 parts per million) obtained in Cambrian, Ordovician, and Silurian limestones in Wisconsin (*6, 7*).

Four standard oceanographic stations were made in Grise Fiord, and three in South Cape Fiord. Two stations were made in Jones Sound, several miles south of Grise Fiord, for comparison with conditions in the fiords. Salinity samples were determined by the Woods Hole Oceanographic Institution. Unfiltered samples, which had been either frozen or preserved in mercury, were analyzed in this laboratory. Total dissolved inorganic $NO_2^- + NO_3^-$, PO_4^{2-}, and reactive Si were determined by standard methods (*8*), with a Klett colorimeter. The significances of the differences in nutrient concentrations between the two fiords, between South Cape Fiord and Jones Sound, and between Grise Fiord and Jones Sound were determined by the nonparametric Mann-Whitney U test.

The oceanography of arctic Canada has been discussed most recently by Collin and Dunbar (*9*). The waters of Jones Sound are derived from the upper layers of the Arctic Ocean, and most of that water arrives in the sound from the west via Cardigan Strait and Hell Gate. A small proportion flows in from the east from Smith Sound via Glacier Strait. Bailey (*10*) reported ". . . an eastward flow taking place in the surface layer across the section (*i.e.*, the width of Jones Sound). The cold water layer (of intermediate depth), however, moved westward on the north side and eastward on the south side. Movements in the deep waters although slight were generally eastward." Earlier physical (*10, 11*) and chemical (*12*) studies in this area were carried out during ice-free summer seasons, after the annual phytoplankton development depleted the nutrient content of surface waters, and are not comparable with the present work.

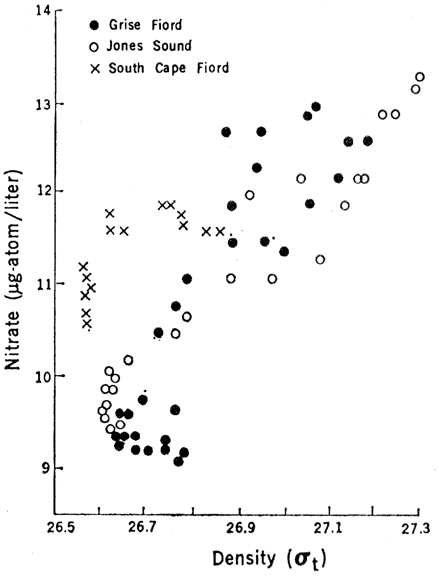

Fig. 1. Relation of dissolved inorganic nitrate to density (σ_t) in waters off southern Ellesmere Island, Northwest Territories, Canada, May 1969.

The results (*7*) for nitrates are shown graphically in Fig. 1. In comparing nutrient concentrations with those in South Cape Fiord, only data from 0 to 75 m in Grise Fiord and Jones Sound were used, since the maximum observed depth in South Cape Fiord was 87 m. Similarly, the data from 0 to 200 m in Jones Sound were compared with all those in Grise Fiord.

There are no significant differences in phosphate concentrations between the two fiords or between each fiord and Jones Sound.

Nitrates, in contrast, show significantly larger concentrations in South Cape Fiord than in Grise Fiord ($U = 3.88$, $P < .001$) and in Jones Sound ($U = 2.50$, $P < .01$). There is no significant difference between Grise Fiord and Jones Sound ($U = 1.153$, $P > .05$).

Silicates average higher in South Cape Fiord than in Grise Fiord. It is not certain that the difference is significant, however. The first analysis of 40 samples (18 from South Cape and 22 from Grise Fiord) yielded average silica concentrations of 18.8 μg-atom/liter in South Cape Fiord and 16.2 μg-atom/liter in Grise Fiord, but the difference is not quite significant. A second analysis on 27 of those samples (13 in South Cape and 14 in Grise Fiord), however, showed averages of 21.3 μg-atom/liter in South Cape Fiord and 17.1 μg-atom/liter in Grise Fiord. This difference is highly significant ($U = 2.609$, $P < .01$).

Analytical problems associated with newly thawed seawater samples of this type have been reported (*13, 14*).

The fact that the differences in silica concentration between the fiords were very nearly significant in the first set of analyses and highly significant in the second set suggests that a real difference does exist between the fiords, but perhaps was partly obscured by the freezing effect investigated by Burton *et al.* (*14*). It seems likely that the silica concentrations in South Cape Fiord, like the nitrate concentrations, are significantly greater than those in Grise Fiord and Jones Sound.

Chalk and Keeney (*6*) found that ". . . nitrate and ammonium in limestones were present entirely as soluble salts, . . . retained by physical entrapment, and . . . released eventually on the weathering of the rock." Glacial erosion, abrasion, and scouring of comparable rocks in South Cape Fiord must have an effect equivalent to weathering, thereby releasing physically entrapped soluble nitrogen salts into the waters of South Cape Fiord.

In contrast, if phosphate exists in the rocks as apatite, which is most likely (*5*), little dissolution would be expected at the normal *p*H of seawater unless glacial grinding caused the production of an amorphous form of phosphate through alteration of the crystal structure. The phosphate results are consistent with the hypothesis that such a change does not occur, and that no significant dissolution of phosphate from these limestones results from glacial activity.

These observations suggest that glacial discharge in South Cape Fiord does increase the concentrations of nitrate and probably silicate in seawater adjacent to the glacier. In this comparison, the significant differences are between concentrations of nutrients in the upper 75 m of the two fiords. In Jones Sound the euphotic zone is confined to the upper 25 m (*15*). If only the concentrations of nutrients within the euphotic zone depths of the two fiords are compared, nitrates in South Cape Fiord average 18 percent greater than those in Grise Fiord, a notable enrichment of a vital element.

I measured phosphate and silicate concentrations in the summers of 1961, 1962, and 1963, and nitrate concentrations in 1962 and 1963, in the waters on the south side of Jones Sound throughout the periods of phytoplankton development. In each summer, phosphates showed relatively little depletion but nitrates were completely exhausted in and below the euphotic zone, and the plant cells exhibited symptoms of nitrate deficiency (*15*). Silicates were substantially reduced each year, but were not completely exhausted. It is interesting that these two nutrients in critical supply for phytoplankton development in arctic waters are those which appear to be augmented by glacial activity, at least in South Cape Fiord.

S. Apollonio
Fisheries Research Station,
Department of Sea and Shore Fisheries,
West Boothbay Harbor, Maine 04575

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5 September 1972; revised 26 December 1972

Volcanic Production Rates: Comparison of Oceanic Ridges, Islands, and the Columbia Plateau Basalts

Abstract. *New potassium-argon age data from the Columbia Plateau suggest a basalt production rate of 10^8 cubic meters per year during a middle Miocene volcanic episode. This is two to three times the production rate in some oceanic islands, and about four to six times the production rate in spreading mid-oceanic ridge systems.*

The most spectacular accumulations of basaltic rock on the earth are the mid-oceanic ridge systems, the oceanic islands, and the great plateau basalts. According to Holmes (*1*) there are only four plateau basalt accumulations which exceed 2×10^5 km³ in volume: the Deccan of India, which is the largest; part of Western Siberia; the Parana of South America; and the Columbia Plateau, which is the youngest of the four. Sea floor spreading, which is best understood to result from crustal extension accompanied by dike injection at oceanic ridge crests, would appear to have been a fairly continuous activity, at least since the late Mesozoic. Using estimated spreading rates, Menard (*2*) calculated that this crustal extension requires the addi-

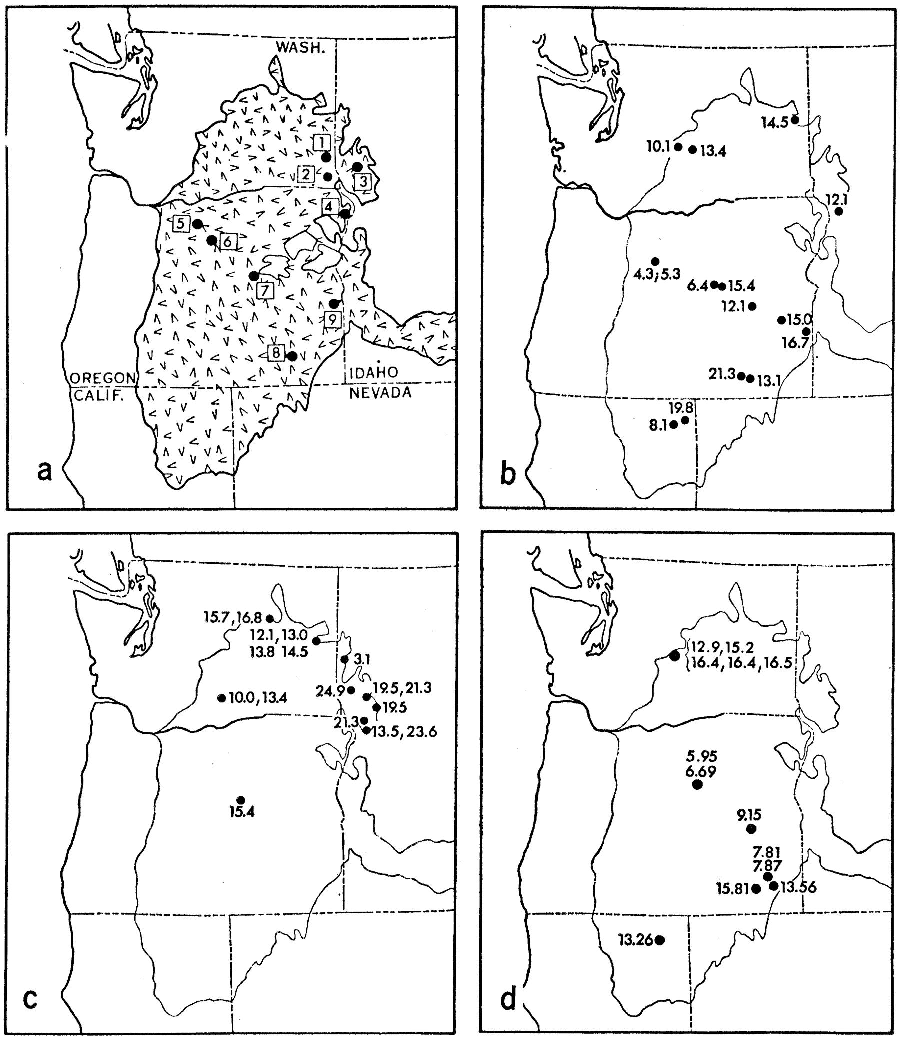

Fig. 1. (a) Map showing the limits of the plateau basalts of the Pacific Northwest and the locations of the nine sections examined in the study reported here. The outline of the plateaus includes the eastward-extending Snake River Plain, but the basalts of the Washington and Oregon coast are excluded. See Table 1 for exact locations and descriptions of the vertical extent and number of lavas in each section. (b–d) Maps showing potassium-argon ages in millions of years: (b) given by Evernden and James (*14*); (c) given by Gray and Kittleman (*13*); and (d) given by Dalrymple *et al.* (*15*) for Oregon and California, and by Holmgren (*16*) for Washington.