



**Figure 2. Soil profile on Prospect drift at Mount Fleming showing salts and deep oxidation.**

quency declines with age of the deposit, and the number of boulders that are fragmented *in situ* (boulder shadows), ventifacted, planed to the surface, pitted, and fractured increases with time. Morphologic features increasing with time include solum thickness, depths of ghosts and visible salts, salt morphogenetic stage, and depth to ice-cemented frost table.

To date, more than 1,000 soils and salt encrustations have been analyzed for water-soluble salts. A regional picture of salt distribution is evolving for the McMurdo Sound region which relates to precipitation patterns (figure 1). In areas

within 50 kilometers of the coast, predominant ions in soil-water extracts are  $\text{Na}^+$  and  $\text{Cl}^-$ . Ratios of these ions and others are similar to those calculated from antarctic seawater analysis. Since they occur in soils not having been influenced by marine incursions, the salts are of marine-aerosol origin. At elevations above 1,500 meters and/or distances greater than 100 kilometers from the open sea, soils contain dominantly  $\text{Na}^+$  and  $\text{NO}_3^-$ . Several investigators (Parker et al. 1977; Wilson and House 1965) have shown that the nitrate is contained in snow falling on the polar plateau. This snow subsequently is blown by katabatic winds for distances exceeding 1,000 kilometers to ice-free areas in the Transantarctic Mountains, where it sublimates, leaving a residue of salts. In a third zone, intermediate in elevation and distance from the open sea,  $\text{Na}^+$  or  $\text{Ca}^{2+}$  and  $\text{SO}_4^{2-}$  are prevalent. The sulfate may be partially of marine-aerosol origin and partially from polar snow (Sulek et al. 1979).

Concentrations of ions possibly contributed by rock weathering ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{K}^+$ ) are low compared with those brought in by precipitation. Therefore, the chemistry of cold desert soils in Antarctica is influenced more by precipitation than by chemical weathering (Bockheim 1981).

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## A partial geochemical analysis of the Onyx River

WILLIAM J. GREEN and DONALD E. CANFIELD

*School of Interdisciplinary Studies  
Miami University  
Oxford, Ohio 45056*

While Lake Vanda has been the subject of several geochemical (e.g., Angino, Armitage, and Tash 1965; Jones and Faure

1969) and biological investigations (e.g., Benoit, Hatcher, and Green 1971) over the past two decades, little attention has been given to the lake's major feeder stream, the Onyx River. As part of a study that focuses on the transport, speciation, and fate of biologically important trace metals and nutrients in the Vanda-Onyx system, we have had an opportunity to determine a number of chemical constituents in the river under a range of flow conditions.

The Onyx originates at the Wright Lower Glacier, at the eastern end of Wright Valley, and flows some 27 kilometers westward (away from the sea) into Lake Vanda. Along its course, depending on temperature, it may be fed by tributary streams derived from several smaller glaciers occupying hang-

ing valleys above the floor of Wright Valley (Nichols 1971). Water depths in the Onyx are typically .5 meter, and the channel is perhaps 3 to 6 meters wide.

For the past 12 years, investigators from the New Zealand Ministry of Works (Anderton and Fenwick 1976; Chinn 1975) have been carrying out hydrological studies in the antarctic dry valleys. This work has included a detailed set of flow measurements taken at a permanent weir site on the Onyx River near Vanda station. Stream discharges monitored over the period 1969–81 showed considerable annual variations, ranging from 15 million cubic meters in 1970–71 to zero in 1977–78, and averaging about 3 million cubic meters (Chinn personal communication). No systematic chemical analyses on Onyx River water were undertaken during this time.

Table 1 lists the concentrations of major ions and silica in the Onyx River, along with temperature, dissolved oxygen, pH, and flow rate recorded at the Vanda weir. Dates in the left-hand column indicate the month, day, and time when

samples were taken. As a check on our analyses, we computed millimoles of positive and negative charge; these appear in columns 13 and 14. The percentage difference (with respect to anionic charge) is given in column 15.

We found the waters of the Onyx to be slightly basic and generally saturated with dissolved oxygen. In the first few days of Onyx flow there is a sharp decrease in major ion and silica concentrations, suggesting that during early flow salts derived from weathering of valley soils are being solubilized and transported by the river. During the remainder of the flow season the major ion and silica concentrations all appear to remain fairly constant.

The ionic content of the Onyx is considerably lower than that of average world river water (Livingstone 1963). Among the major ions, only chloride is comparable to that reported by Livingstone (1963). We find in the Onyx roughly equimolar concentrations of sodium and chloride, indicating that the relatively high chloride values are probably attributable to

**Table 1. Concentrations of major ions and silica in the Onyx River**

Month/day/ time of day	(1) Temperature <sup>a</sup>	(2) Oxygen <sup>b</sup>	(3) pH	(4) Flow <sup>g</sup>	(5) Silica <sup>b</sup>					
12/15/0945	—	—	—	66	—					
12/16/2200	2.0	13.2	7.9	77	3.45					
12/23/1400	—	13.4	7.4	230	3.34					
12/24/0900	2.0	13.7	—	328	3.04					
12/25/1300	3.5	12.4	—	440	2.86					
12/26/2300	2.8	13.2	7.5	422	3.07					
12/27/100	2.0	13.6	—	449	3.09					
12/27/2100	—	—	—	750	—					
12/28/0900	5.0	13.6	—	988	2.93					
12/28/2230	4.5	—	—	676	2.93					
1/6/1415	3.0	12.5	—	661	2.68					
Average world river water <sup>f</sup>									13	

  

Month/day/ time of day	(6) Calcium <sup>b</sup>	(7) Magnesium <sup>b</sup>	(8) Sodium <sup>b</sup>	(9) Potassium <sup>b</sup>	(10) Chlorine <sup>b</sup>	(11) Sulfate <sup>b</sup>	(12) Bicarbonate <sup>b</sup>	(13) Positive charge <sup>c</sup>	(14) Negative charge <sup>c</sup>	(15) Percentage difference
12/15/0945	6.72	1.99	7.20	1.67	11.95	7.35	23.0	0.856	0.867	1.3
12/16/2200	6.40	1.82	7.07	1.56	11.10	6.30	23.0	0.818	0.821	0.3
12/23/1400	5.39	1.72	5.30	1.39	8.35	5.25	22.5	0.714	0.712	0.2
12/24/0900	4.96	1.61	4.93	1.33	8.01	4.80	18.4	0.627	0.627	0.0
12/25/1300	4.41	1.29	4.47	1.23	7.10	4.50	15.2	0.551	0.543	1.5
12/26/2300	5.01	1.55	5.03	1.36	7.60	4.70	19.8	0.631	0.636	0.8
12/27/1000	5.40	1.71	5.33	1.40	8.16	5.50	19.0	0.678	0.655	3.5
12/27/2100	4.98	1.52	4.98	1.32	8.01	4.25	17.5	0.621	0.601	3.3
12/28/0900	4.96	1.48	4.96	1.32	7.60	5.20	17.5	0.621	0.609	2.0
12/28/2230	4.75	1.44	4.90	1.32	7.76	4.90	17.1	0.602	0.601	0.2
1/6/1415	4.11	1.29	4.20	1.09	6.35	4.24 <sup>e</sup>	16.7	0.522	0.541	3.7
Average world river water <sup>f</sup>	15	4.1	6.3	2.3	7.8	11	58			

<sup>a</sup>In °C.

<sup>b</sup>In milligrams per liter.

<sup>c</sup>In millimoles.

<sup>d</sup>Dashes indicate no data.

<sup>e</sup>Estimated.

<sup>f</sup>From Livingstone (1963).

<sup>g</sup>In liters per second.

incorporation of halite into valley soils by the airborne transport of ocean salts and subsequent solubilization by the Onyx.

Compared with rivers of the temperate zone, there is little change in ionic concentration with flow rate changes. This is seen most clearly in the data sets for 23 and 28 December 1980. Here flow rates differed by about 400 percent, but changes in cation or anion concentrations amounted to only 13 percent. We found no evidence of strong or irregular variations in composition that might be taken as evidence that groundwater is entering the Onyx.

Table 2 gives concentrations of total phosphorus, dissolved orthophosphorus, total dissolved phosphorus, inorganic nitrogen species, total and dissolved iron, and total copper. Total phosphorus values are low and comparison of columns 2 and 4 shows that most of the phosphorus in the Onyx is present in particulate form. If this particulate phosphorus tends to settle out in the shallow eastern end of Lake Vanda (the "Vanda Estuary"), this could be one reason why the lake is so starkly unproductive.

High nitrate nitrogen values were obtained early in the season, but these fell rapidly with time. Nitrate also was measured in early samples but was not detected after 16 December. We suspect that our first sample reflected to a large extent the composition of the biologically active Bull Pond, which lies just above the weir. Ammonia was not detected.

Average iron concentrations in the Onyx were high; this is consistent with the presence of dolerite sills (McKelvey and Webb 1962) and iron-enriched soils (Ugolini 1964). Like phosphorus, iron was present largely in particulate form, at levels ranging from 210 to 360 micrograms per liter of total iron. Copper concentrations in the Onyx, as in most unpolluted natural waters, were low, the highest measured value being 2.5 micrograms per liter.

On the morning of 6 January 1981, we sampled the ice of Wright Lower Glacier and the waters of the Onyx at four locations along its course to Vanda (see table 3). For all of the major ions and silica, we observed a regular increase in concentration along the length of the river—a trend first observed by Jones and Faure (1969) for the major cations. Total phos-

**Table 2. Nutrients and selected trace elements in the Onyx River**

(1) Month/day/time	(2) Total phosphorus	(3) Dissolved orthophosphate phosphorus	(4) Total dissolved phosphorus	(5) NO <sub>3</sub> -N	(6) NO <sub>2</sub> -N	(7) NH <sub>3</sub> -N	(8) Total iron	(9) Dissolved iron	(10) Total copper
12/15/0945	9.4	— <sup>a</sup>	—	88.8	4.8	N.D. <sup>b</sup>	350	—	2.5
12/16/2200	10.0	0.8	—	50.1	3.6	N.D.	270	1.5	0.9
12/23/1400	6.8	1.3	1.8	10.1	N.D.	N.D.	320	8.0	N.D.
12/24/0900	4.8	—	2.6	8.1	N.D.	N.D.	254	26	0.6
12/25/1300	—	0.9	2.8	6.6	N.D.	N.D.	210	13	0.7
12/26/2300	6.2	1.8	—	4.8	N.D.	N.D.	237	6.5	0.6
12/28/0900	7.3	—	1.1	8.4	N.D.	N.D.	360	12	1.5
1/6/1415	4.4	0.8	—	3.3	N.D.	N.D.	290	21	0.4
1/6/2200	5.2	—	1.0	4.5	N.D.	N.D.	340	—	0.6

Note. All values in micrograms per liter.

<sup>a</sup>Dashes indicate that no analysis was attempted.

<sup>b</sup>N.D. = Not detected.

**Table 3. Major ions and nutrients at various locations along the Onyx River on 6 January 1981**

Location	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Bicarbonate	Silica	Total phosphorus	NO <sub>3</sub> -N
Wright Lower Glacier ice	0.10	0.37	0.64	0.10	1.35	N.D. <sup>a</sup>	N.D.	0.1	— <sup>b</sup>	32.7
Lake Brownsworth	2.22	1.08	2.88	0.69	4.58	4.4	8.3	1.66	3.6	21.5
Onyx near the Meserve Glacier	3.04	1.12	3.31	0.79	5.37	5.0	11.4	1.91	6.8	18.2
Onyx near Bull Pass	3.38	1.16	3.63	0.93	5.76	6.1	13.0	2.21	12.9	19.4
Onyx at Vanda Weir	4.11	1.29	4.20	1.09	6.35	7.2	16.7	2.68	4.4	3.3

<sup>a</sup>N.D. = Not detected.

<sup>b</sup>No analysis was attempted.

phorus also increased along the Onyx as far as Bull Pass, but between the pass and the Vanda Weir, it decreased by a factor of three. We suspect that an active algal community just above Bull Lake may be acting as a phosphorus sink.

Unlike phosphorus, which is derived from the soils of the valley and whose concentration is augmented by contact with these soils, nitrate is apparently derived from the ice of Wright Lower Glacier. The concentration of this nutrient decreases downstream, perhaps in response to its utilization by soil and aquatic organisms. As with phosphorus, the most pronounced change again occurs between sites 4 and 5, which may be another indication of an active biological community above Bull Lake.

As part of this research, we have also measured major ions, nutrients, and trace elements throughout the water column of Lake Vanda and in the lake ice and sediments. Determinations of chromium, manganese, cobalt, nickel, zinc, lead, and cadmium are in progress for all compartments of the Vanda-Onyx system. We hope to report shortly on trace element and nutrient residence times and equilibrium speciation and to comment on the possible origin and distribution of salts in Lake Vanda. A more detailed article on the Onyx is in preparation.

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1980 to 29 January 1981, and Lee and Jones from 8 December 1980 to 21 December 1981.

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## Provenance of feldspar in till on Mount Fleming, southern Victoria Land

GUNTER FAURE and KAREN S. TAYLOR

*Department of Geology and Mineralogy  
and  
Institute of Polar Studies  
The Ohio State University  
Columbus, Ohio 43210*

During the 1980-81 field season, from 5 November to 11 December 1980, we collected a large number of samples of glacial deposits from localities in southern Victoria Land

reachable by UH-1N helicopter from McMurdo. The feldspar in these samples is being analyzed in our laboratory for dating by the rubidium-strontium (Rb-Sr) method to detect a component that may have been transported from the Precambrian Shield of East Antarctica by the ice sheet that covered the Transantarctic Mountains prior to the cutting of the major valleys (Barrett and Powell 1981; Faure and Taylor 1980).

A sample of till was collected for us by George Denton from a rock basin on the southeast flank of Mount Fleming (77°33'S 160°08'E). The till is highly indurated but uncemented, unsorted, and unstratified with a silty to sandy matrix (figure 1A). Clasts ranging from 0.4 to 3 centimeters constitute 20 percent of the till and are composed of sandstone (60.6 percent by weight), siltstone (34.5 percent), black shale (4.2 percent), coal (0.4 percent), and white quartz (0.4 percent). Quartz has a unimodal distribution with an abundance peak in the 125- to 500-micrometer fraction coincident with quartz grains in