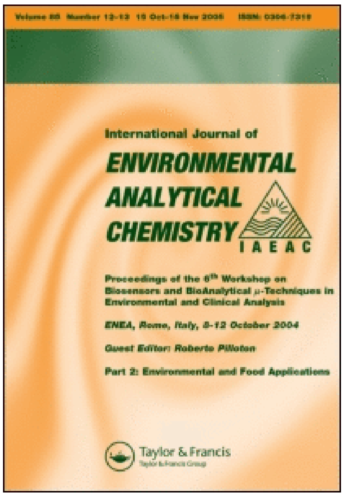

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Variation of Major and Trace Elements in Some of the Lakes at Terra Nova Bay (ANTARCTICA), December 1990-February 1991

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VARIATION OF MAJOR AND TRACE ELEMENTS IN SOME OF THE LAKES AT TERRA NOVA BAY (ANTARCTICA), DECEMBER 1990-FEBRUARY 1991

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The data regarding the chemical composition of lake waters sampled in the area of Edmonson Point, Carezza, Inexpressible Island, Andersson Ridge and Tarn Flat will be presented and discussed in this paper. The averages of total dissolved solids (TDS) of each lake range from 95 mg l^{-1} to 3765 mg l^{-1}. The chemical composition is characterized by high contents of Na and Cl.

During the sampling period the salinity showed constant or increasing values. The processes that condition this behaviour will be examined and discussed.

In general, the concentration of trace elements does not reveal any significant trend over time, and only the lakes' nickel content changes with respect to the increase in salinity.

KEY WORDS: Antarctica, chemical composition, major and trace element.

INTRODUCTION

Terra Nova Bay was extensively studied during the 1986–1989 Italian antarctic expeditions. From a geochemical point of view, the most important results obtained during the previous studies[1-3] can be summarized as follows:

– Water chemistry is greatly conditioned by the contribution of marine origin salts, and subordinately by the processes of rock leaching. As a consequence, sodium and chloride are the dominant ions, followed by magnesium and sulphate, while calcium and potassium are relatively less abundant.

– Trace element levels do not exhibit anomalous values. The highest values of some trace elements (e.g. Ni and Mo) were found to correspond to higher background levels due to the particular lithology of the outcropping rocks.

With the aim of collecting new data on the processes that condition the natural variability of trace element contents in the superficial waters, during the sixth Italian expedition

(1990–1991) the chemical composition of the waters from some lakes was studied through sampling repeated from four to ten times at each site.

The lakes were selected according to their distance from the coast and to the lithological characteristics of catchment rocks.

Knowledge of the processes that determine the variability of the natural levels will be useful in evaluating the contributions due to anthropic activity with particular regard to the Italian base.

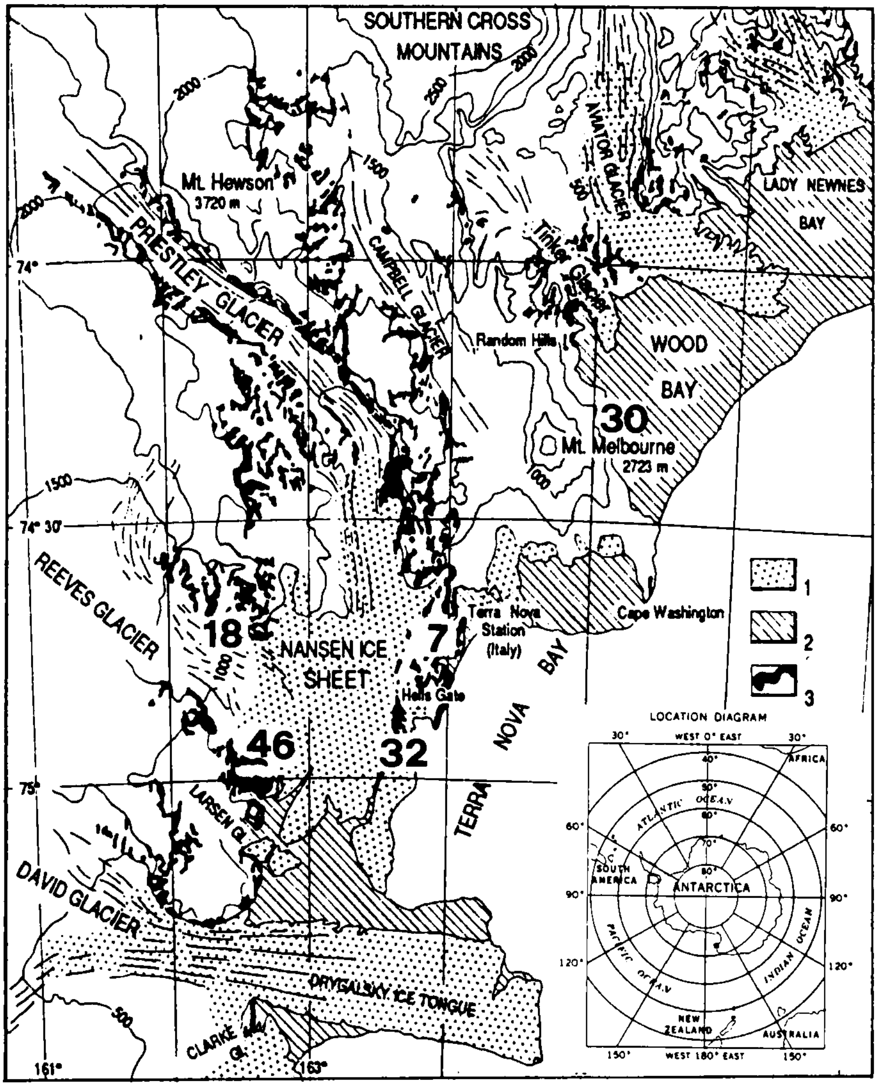

Figure 1 Map of sampling sites: 1—Floating ice shelves, ice tongues and glacier tongues; 2—Fast and bay ice; 3—Ice-free area.
7—Carezza Lake, 18—Andersson Ridge; 30—Edmonson Point, 32—Inexpressible Island, 46—Tarn Flat.

Table 1 Geographical position and morphometric data of sampling points at Terra Nova Bay. *% of iced surface at the end of December.

Ref. n°	*Lake*	*Coordinates*	*Altitude m (a.s.l.)*	*Distance from the sea (km)*	*Area (m^2)*	*Depth (m)*	*Ice* %*
30	Edmonson point	74°20′S–165°08′ E	20	0.5	3970	2	0
7	Carezza Lake	74°43′S–164°03′ E	170	1.0	7890	2	30
32	Inexpressible Island	74°54′S–163°41′ E	26	0.8	6760	1.5	40
46	Tarn Flat	74°58′S–162°30′ E	70	35	7650	3.5	10
18	Andersson Ridge	74°43′S–162°37′ E	700	45	—	—	95

EXPERIMENTAL

Figure 1 shows the study area and the location of the sampling points.

In Table 1 the geographical position and some morphometric data on the lakes studied are reported.

From the lithological point of view, Terra Nova Bay is characterized by a great variety of rocks. Granites and Tonalites outcrop in the areas of Andersson Ridge and Tarn Flat, Quartzdiorites, Anphibolites and Gabbros in the areas of Inexpressible Island and Carezza Lake, and volcanic rocks in the Edmonson Point area, which is located on the slopes of Mt. Melbourne.

Waters were collected near the sides of the lakes and when possible, at two sites opposite one another.

44 water samples were analyzed for physical and chemical properties.

Conductivity and pH were measured in situ, while hydrogen carbonates were analyzed, by titration, immediately after sample collection[4].

The laboratory analytical procedures were performed as follows:

The water samples were filtered through a 0.45 μm cellulose acetate filter.

A first aliquot of 0.5 l was immediately extracted with APDC in chloroform at pH 3.5. After re-extraction in aqueous phase Mo, V, Co and Ni were analyzed by graphite furnace AAS.

For Pb and Cd the procedure was the same, but an extraction at pH 9.3 with dithizon in chloroform was used.

The major cations (Na, K, Ca, Mg) and SiO_2 were determined by ICP. The major anions (Cl, F, NO_3 and SO_4) were determined by ion chromatography using a Dionex HPIC AS4A (4 x 250 mm) column for ion separation with a Dionex HPIC AG4A (4 x 50 mm) guard column. The eluent was a mixture of 2.2 m mol l^{-1} $NaHCO_3$ and 2.8 m mol l^{-1} Na_2CO_3, with a flow rate of 2 ml min^{-1}. Eluent conductivity was suppressed using a Dionex AMSS anion micro membrane suppressor.

Diluted sulphuric acid (0.025 m mol l^{-1} H_2SO_4) was used for suppressor regeneration at a flow rate of 5 ml min^{-1}. Sample introduction was via a valve with a 50 μl loop.

Table 2 Physical-chemical parameter and major, minor and trace element contents of studied waters. "." Not determined.

Ref.	*Date*	*T* °*C*	*pH*	*Eh* *mv*	*C* μs cm^{-1}	*Ca*	*Mg*	*Na*	*K*	*HCO3*	*SO4*
						mg/l					
7	22-12-90	1.8	8.91	466	200	10.2	2.4	23	2.3	39	10.1
7	22-12-90	3.7	9.04	479	220	11.4	2.8	25.3	2.6	42.7	12.2
7	29-12-90	3.8	9.11	296	310	13.2	3.7	34.7	3.6	59.2	9.1
7	29-12-90	4.5	9.18	299	320	12.9	3.7	36.3	3.6	53.7	12.5
7	9-1-91	5.3	7.09	561	450	17.1	5.4	52.9	5.2	60.4	21.1
7	9-1-91	.	7.45	512	420	14.8	5	49	4.9	57.3	17
7	18-1-91	4	9.09	528	480	17.7	5.9	55.2	5.5	61.6	26.4
7	18-1-91	8.1	9.08	517	460	18.3	5.6	53.6	5.3	60.7	20.9
7	31-1-91	1	9.1	498	590	19.3	6.6	61.6	6.2	62.8	18.5
18	26-12-90	2.5	9.27	324	210	4.3	2.8	30.1	2.6	17.4	14.6
18	5-1-91	3.5	7.92	274	310	5.7	2.8	26.7	2.4	23.2	14.4
18	5-1-91	3	7.2	308	330	6.9	4.1	43.5	3.4	17.7	15.1
18	13-1-91	2.2	6.3	.	390	7.5	4.3	42.8	3.4	15.9	19.2
18	13-1-91	1.5	6.41	.	.	8.3	4.4	42.8	3.5	15.2	17.7
18	19-1-91	2.5	6.5	.	350	7.5	4.4	44.2	3.3	16.5	19.4
18	19-1-91	.2	6.7	.	250	5	3	32.4	2.3	12.8	13.4
30	20-12-90	5	10	342	190	1.7	1.9	27.6	2.1	17.1	2.9
30	20-12-90	7	9	427	220	1.7	1.9	28.3	2.1	33.6	2.8
30	26-12-90	7.5	9.81	287	200	2.1	2.3	30.1	2.4	21.4	2.9
30	26-12-90	7.8	9.8	290	200	2	2.2	29.2	2.4	18.3	3.4
30	3-1-91	10.5	9.66	277	360	3.8	4	49.7	4.4	31.7	3.8
30	3-1-91	11.5	9.63	615	450	3.8	4	49.7	4.7	32.3	3.6
30	11-1-91	0	9.57	598	600	5.6	6.6	77.3	6.6	45.1	4.8
30	11-1-91	0	9.2	554	550	5.7	6.5	77.3	6.6	45.8	5
30	21-1-91	8.2	9.56	540	710	6.8	7.4	89.9	7.9	50.6	6
30	21-1-91	8.5	9.79	525	740	6.9	7.4	89.2	7.5	51.9	6.2
30	5-2-91	0	9.25	415	870	8.9	9.1	116.8	9.7	43.9	7.7
30	5-2-91	0	9.37	473	850	8.2	8.9	113.6	9.4	47.6	8.2
32	23-12-90	7	7.98	329	4260	35.4	70.8	680.8	48.9	61	283.2
32	23-12-90	7	8.22	328	4230	35	69.6	680.8	48.9	57.3	307.2
32	30-12-90	.2	7.73	325	4080	36	61.2	623.3	46.5	58	273.6
32	30-12-90	2.6	7.87	371	4300	36.4	68.4	680.8	48.9	57.3	307.2
32	10-1-91	.7	7.4	564	5390	40.4	78	901.6	80.2	73.2	345.6
32	10-1-91	.9	7.4	571	5890	47.4	79.2	979.8	76.2	75	336
32	23-1-91	.5	7.27	540	6700	57.2	92.4	1122.4	97.4	109.2	408
32	23-1-91	.5	7.2	536	6330	49.6	92.4	1106.3	87.6	89.7	417.6
32	31-1-91	1.5	7.13	603	7660	65.8	91.2	1311	106.7	96.4	513.6
46	23-12-90	4	7.29	615	420	19.4	7.2	44.8	3.6	75	19.7
46	23-12-90	4	7.73	610	400	19.8	7.4	43.5	3.5	70.8	20.9
46	4-1-91	4.5	7.72	307	390	19.2	6.2	38.6	3.3	62.8	18.2
46	4-1-91	5	7.59	372	400	19.1	6.5	38.6	3.2	64.1	17.3
46	16-1-91	3.1	7.55	.	410	19.9	6.5	39.3	3.2	73.8	18.2
46	16-1-91	3	7.61	.	420	20.4	6.7	38.6	3.3	64.1	19
46	31-1-91	1	7.32	565	470	23.4	7.7	44.8	3.9	63.4	24

RESULTS AND DISCUSSION

Major components.

Table 2 shows the results obtained during the 1990–1991 expedition.

The highest salinity value was found at Inexpressible Island (Electric Cond.= 4230–7750 μS cm^{-1}) and the lowest at Andersson Ridge (Electric Conductivity = 210–390 μS cm^{-1}). Figure 2, which shows the variation of electrical conductivity vs. time, shows that at

Cl	*SiO2*	*F*	*Cd*	*Pb*	*Zn*	*Cu*	*Mo*	*V*	*Ni*	*Co*
			µg/l							
37.9	3.66	.28	.0062	.056	.62	.25	.238	.22	.192	.033
40.4	4.04	.27	.0084	.031	.46	.26	.394	.35	.216	.036
59.1	5.27	.35	.0081	.017	1.74	.46	.324	1.16	.396	.056
61.6	4.91	.36	.0057	.058	.92	.41	.414	1.28	.504	.08
89.5	6.57	.45	.0088	.033	2.7	.83	.592	.204	.632	.088
81.2	7.03	.45	.0071	.028	.76	.364	.416	.304	.468	.108
97.9	7.74	.5	.0036	.036	.88	.03	.432	1.26	.656	.029
93.7	8.02	.48	.	.	.	.	.516	1.36	.756	.034
112.4	8.39	.52	.006	.146	1.34	.38	.	.	.	.
45.8	5.36	.64	.0087	.043	1.04	.276	.244	.42	.296	.036
43	6.3	.66	.016	.036	4.6	.058	.218	.286	.464	.021
72.4	5.02	.72	.	.	.	.	.	.	.	.
75.8	5.52	.67	.0048	.053	1.22	.264	.218	.346	.44	.018
.	7.42	.15	.0172	.032	2.56	.3	.248	.374	.456	.014
74.9	5.11	.66	.008	.048	3.5	.25	.236	.398	.618	.019
55	3.58	.51	.008	.056	2.96	.232	.167	.266	.58	.04
44.2	1.65	.64	.0654	.094	1.9	.72	.754	.36	.256	.033
44.2	1.64	.63	.029	.026	1.1	.38	.578	.28	.16	.03
48.3	1.75	.65	.0078	.022	.66	.224	.	.	.	.
48.1	1.68	.65	.0045	.026	.57	.234	.598	.448	.364	.05
83.3	2.85	.92	.	.	.	.	.788	.472	.592	.068
81.6	3.02	.92	.	.	.	.	.	.	.	.
134.9	4.1	1.34	.0054	.013	.94	.376	.75	.412	.696	.031
136.6	4.12	1.32	.006	.016	.96	.4	.	.	.	.
158	5.64	1.52	.0076	.036	1.14	.5	.82	.5	.72	.066
157.6	4.81	1.54	.0086	.052	1.14	.36	.97	.9	1.02	.04
199	5.75	1.88	.0056	.102	.85	.232	1.152	.828	.776	.041
203.8	5.65	1.86	.0074	.138	1	.252	.6	.278	.32	.063
1153.8	5.4	1.3	.0304	.089	1.98	.712	.678	.136	.564	.07
1153.8	5.55	1.3	.034	1.28	.552	.986	.195	.784	.104	23
1036.6	7.93	1.26	.0174	.036	2.48	.432	1.376	.093	.872	.096
1189.3	5.76	1.3	.0228	.076	2.16	.504	1.312	.19	.904	.128
1498.1	9.37	1.66	.0288	.025	2.46	.568	1.5	.218	1.368	.08
1537.2	10.03	1.62	.0352	.025	2.1	.56	1.38	.208	1.356	.078
1920.6	9.93	1.78	.0432	.036	4.3	1	1.18	1.18	1.128	.05
1920.6	10.33	1.78	.0312	.052	2.52	.784	1.46	1.46	1.464	.071
1821.2	10.1	1.98	.0568	.136	4	1.04	.92	.246	1.432	.06
80.8	8.33	1.4	.0158	.044	1.88	.334	.346	1.74	.196	.028
73	8.17	2	.0134	.104	1.41	.272	.224	1.12	.32	.014
69.2	9.12	2.1	.0066	.041	2.7	.224	.39	2.1	.332	.028
65.3	9.26	2.3	.0026	.028	1.6	.16	.358	1.86	.428	.018
69.2	10.59	2.5	.0152	.044	3.38	.464	.306	2.1	.712	.016
69.2	10.33	2.5	.0092	.076	1.64	.316	.364	2.32	.712	.016
69.6	11.97	2.58	.0049	.084	2.7	.32	.36	1.7	.632	.022

Edmonson Point, Carezza Lake and Inexpressible Island the conductivity increases regularly over time, at Andersson Ridge it increases during January and decreases in February, while at Tarn Flat it remains fairly constant.

The same considerations are valid for the principal components of water. Their distribution vs. time does not seem affected by the ice melting on the surface of the lakes. In fact, it can be noted that Edmonson Point and Tarn Flat, both practically free of ice from the end of December, display a different conductivity pattern (as well as of the other chemical components), which regularly increases in the first lake and is fairly constant in the other.

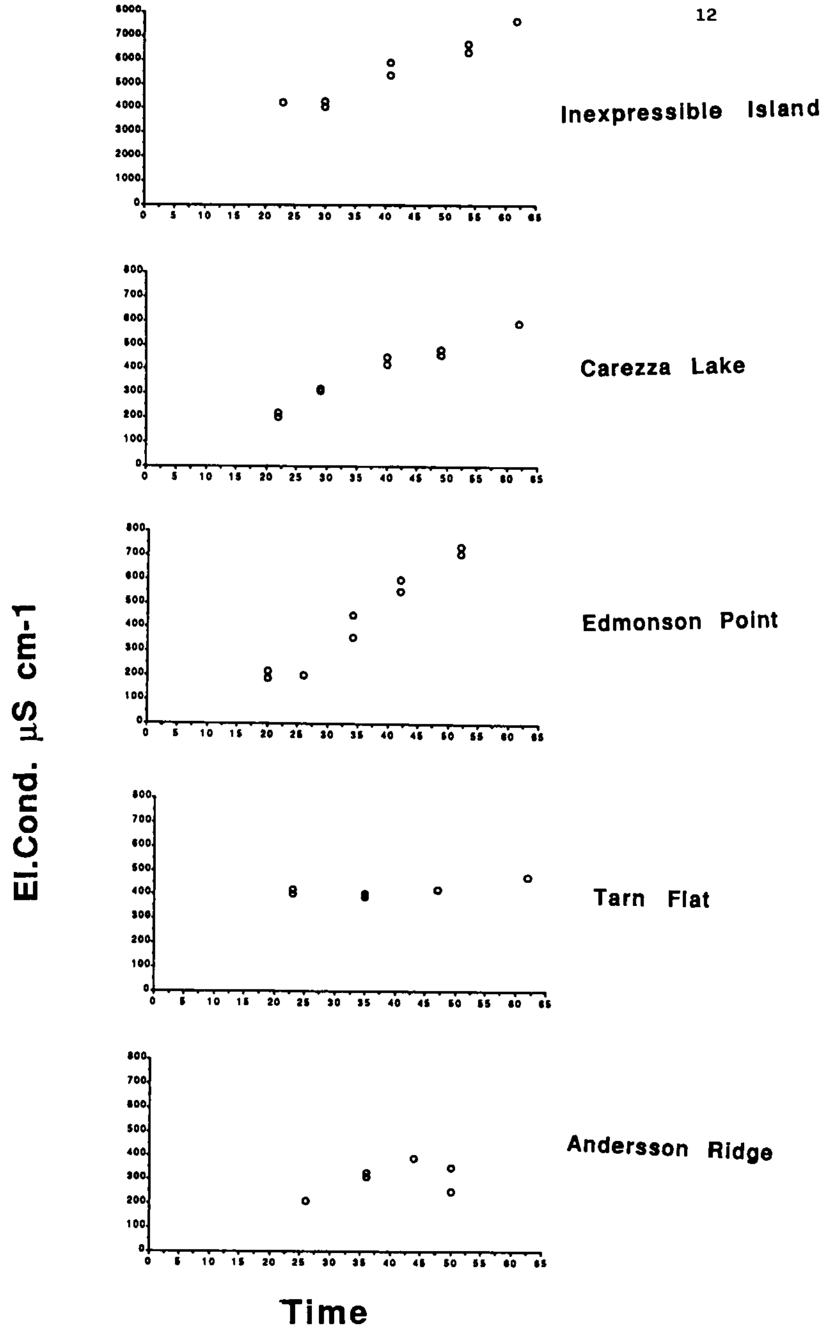

Figure 2 Electrical Conductivity-Time correlation. Time is expressed in number of days starting from December 1.

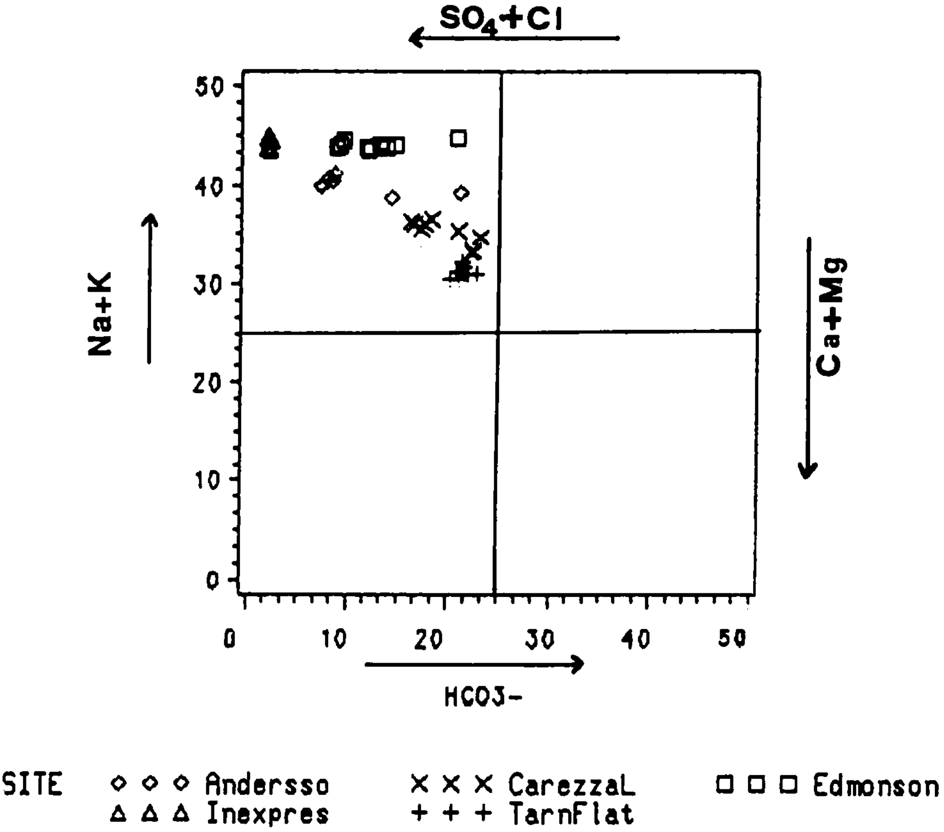

Figure 3 Chebotarev diagram.

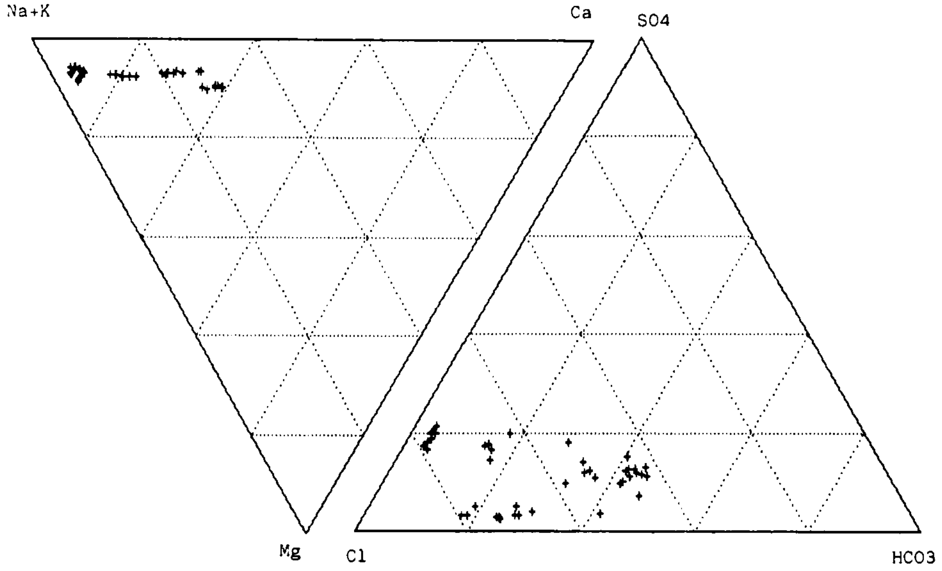

Figure 4 (Na+K)-Ca-Mg and Cl-HCO_3-SO_4 ternary diagrams for 45 samples.

The chemical composition of the waters is shown in Figure 3, according to the Chebotarev diagram.

The samples are characterized by a sodium chloride chemical composition. The samples from Inexpressible Island show ratio values between different components very close to those of sea water, while the samples from Tarn Flat are characterized by a higher Ca-Mg-HCO_3 percentage.

The other samples show a composition that is intermediate between these two types of waters. Edmonson Point waters show a constant cation ratio, while the ratios between SO_4+Cl and HCO_3 vary appreciably.

The variation of percentages between anions and cations are well illustrated in the ternary diagram in Figure 4.

This figure shows that the samples are characterized by a constant percentage of magnesium, a low variability of sulphate and a high variability of Ca, (Na+K), HCO_3 and Cl.

Figure 5 shows the Gibbs Diagram in which the Na/Na+Ca ratio vs. TDS is reported.

Data from the two lakes (Inexpressible Island and Edmonson Point), which are nearest to the sea, demonstrate that the composition of the waters is strongly conditioned by marine origin salts. These waters are characterized by a high Na/Na+Ca ratio (> 0.9), while Tarn

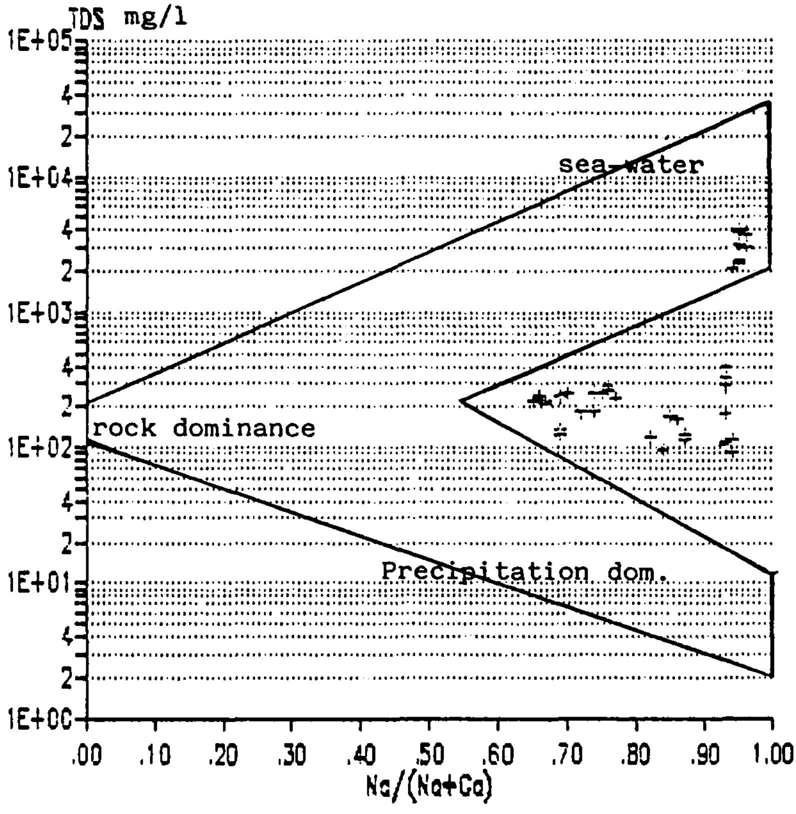

Figure 5 Gibbs diagram.

Table 3 Results of Factor Analysis (Principal Components) using the data on major components and pH of all analyzed samples.

	Factor 1	*Factor 2*
Na	0.96216	0.26335
Cl	0.96186	0.25888
COND	0.95942	0.27481
SO_4	0.95804	0.26801
Mg	0.95555	0.26934
K	0.95428	0.27593
Ca	0.81643	0.54398
SIO_2	0.19476	0.93850
F	0.17525	0.71490
HCO_3	0.48264	0.69618
pH	−0.17557	0.59723

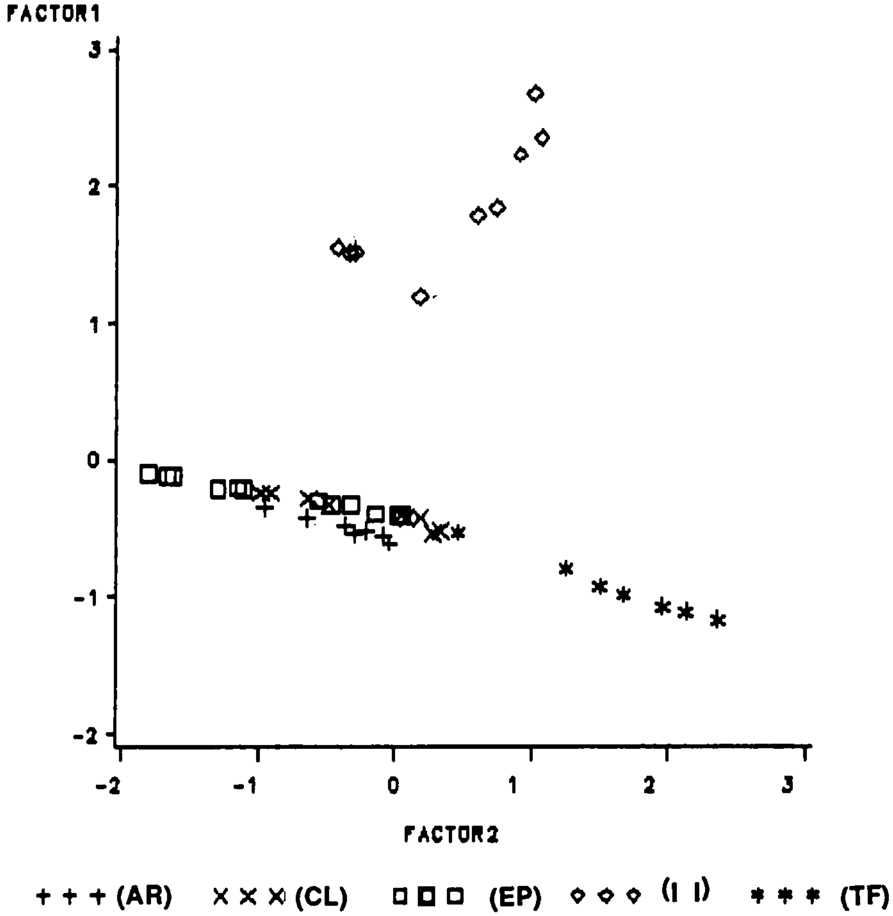

Figure 6 Factor 1–Factor 2 correlation in Andersson Ridge (AR), Carezza (CL), Edmonson Point (EP), Inexpressible Island (II) and Tarn Flat (TF) samples.

Table 4 Results of Factor Analysis (Principal Components) using the data of major constituents and pH of all analyzed samples with the exception of Inexpressible Island data.

	Factor 1	*Factor 2*
Na	0.97820	–0.09654
Cl	0.73730	–0.06749
K	0.97256	–0.05620
COND	0.96864	0.12084
Mg	0.83103	0.52002
F	0.49217	0.41895
Ca	0.08969	0.95286
SIO^2	0.17381	0.94689
SO^4	–0.12065	0.87124
HCO^3	0.39332	0.72300
pH	0.32591	0.61006

Flat and Carezza Lake show a relatively low Na/Na+Ca ratio (0.65–0.75) due to more intensive leaching of rocks.

Generally speaking, the ratio of cations and anions does not show a significant trend vs. time.

A Principal Factor Analysis (PFA) was performed in order to display some of the processes that condition the chemistry of the waters studied.

The factor analysis carried out on all the samples relating to the main constituents showed two factors accounting 72% and 13% respectively, of the global variance. (Table 3).

The first factor shows the high correlations that exist between conductance, chloride, sodium, sulphate, magnesium and potassium, and the second one shows the fluorine-silica correlation.

Figure 6 illustrates the distribution of the factor scores in the plane defined by Factors 1 and 2. The samples collected on Inexpressible Island differ in the far higher values of the first factor in accordance with their high conductivity, 15–20 times greater than that measured in the other sites. The time analysis shows the correlation between the first factor and the sampling date at Inexpressible Island.

The factor analysis was repeated excluding the population of samples collected on Inexpressible Island, so as to eliminate the effects of the overly marked difference in salinity; two significant factors, corresponding to 49 and 32 per cent, respectively, of the variance, were again identified (Table 4).

The first factor shows the close correlation between conductance, chloride, sodium and potassium, and may therefore be linked to the contribution of marine origin salts; the second factor, characterized by silica, sulphate and calcium, may be attributed to rock leaching. Magnesium, fluorine and bicarbonate ions influence both factors.

Figure 7 shows the space distribution of the samples of Factors 1 and 2.

Factor 2 distinguishes the samples according to their origin: the lowest values correspond to Edmonson Point, and then, in increasing order, come Andersson Ridge, Carezza lake and finally Tarn Flat. The scores of Factor 1 at each site are correlated, to the sampling date, and their variability decreases very noticeably when passing to sites characterized by a higher

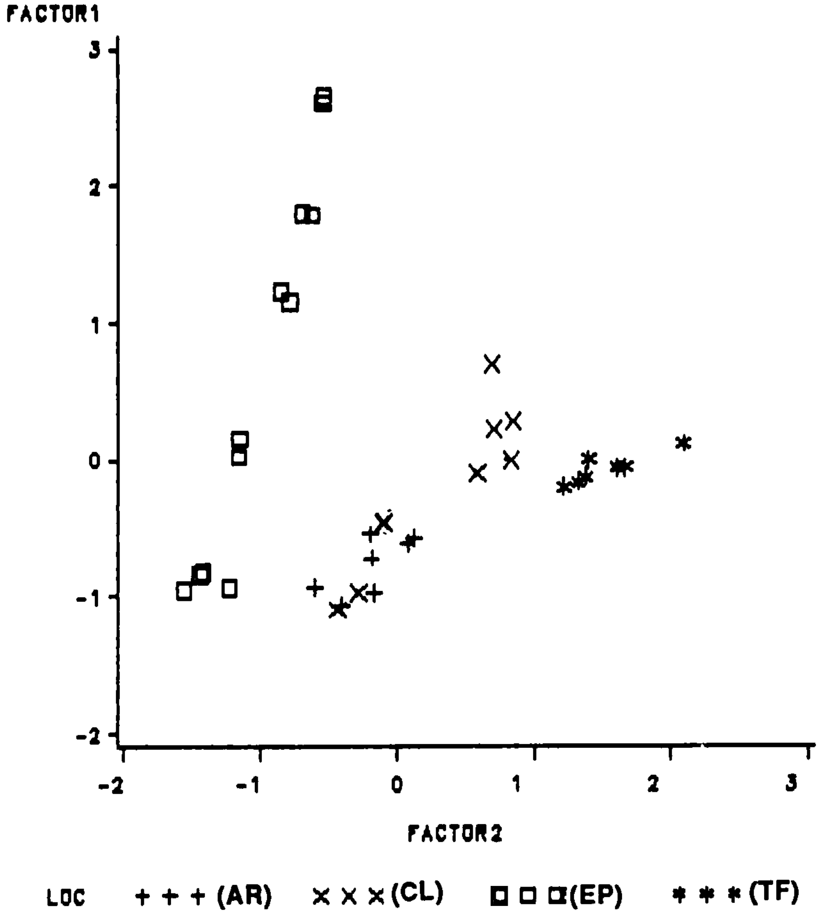

Figure 7 Factor 1-Factor 2 correlation in Andersson Ridge (AR), Carezza (CL), Edmonson Point (EP) and Tarn Flat (TF) samples.

second factor, except for at Andersson Ridge—where due to the high elevation (700 m) the thawing process is considerably slower.

Trace elements

The contents of the trace elements examined are shown in Table 2, while their frequency histograms are reported in Figure 8.

Lead and zinc seem to be randomly distributed in the lakes studied. The highest concentrations of copper, cadmium, nickel, cobalt and molybdenum are present in Inexpressible Island lake. The concentration of vanadium is randomly distributed in all the lakes, with the exception of Tarn Flat lake which shows the highest values.

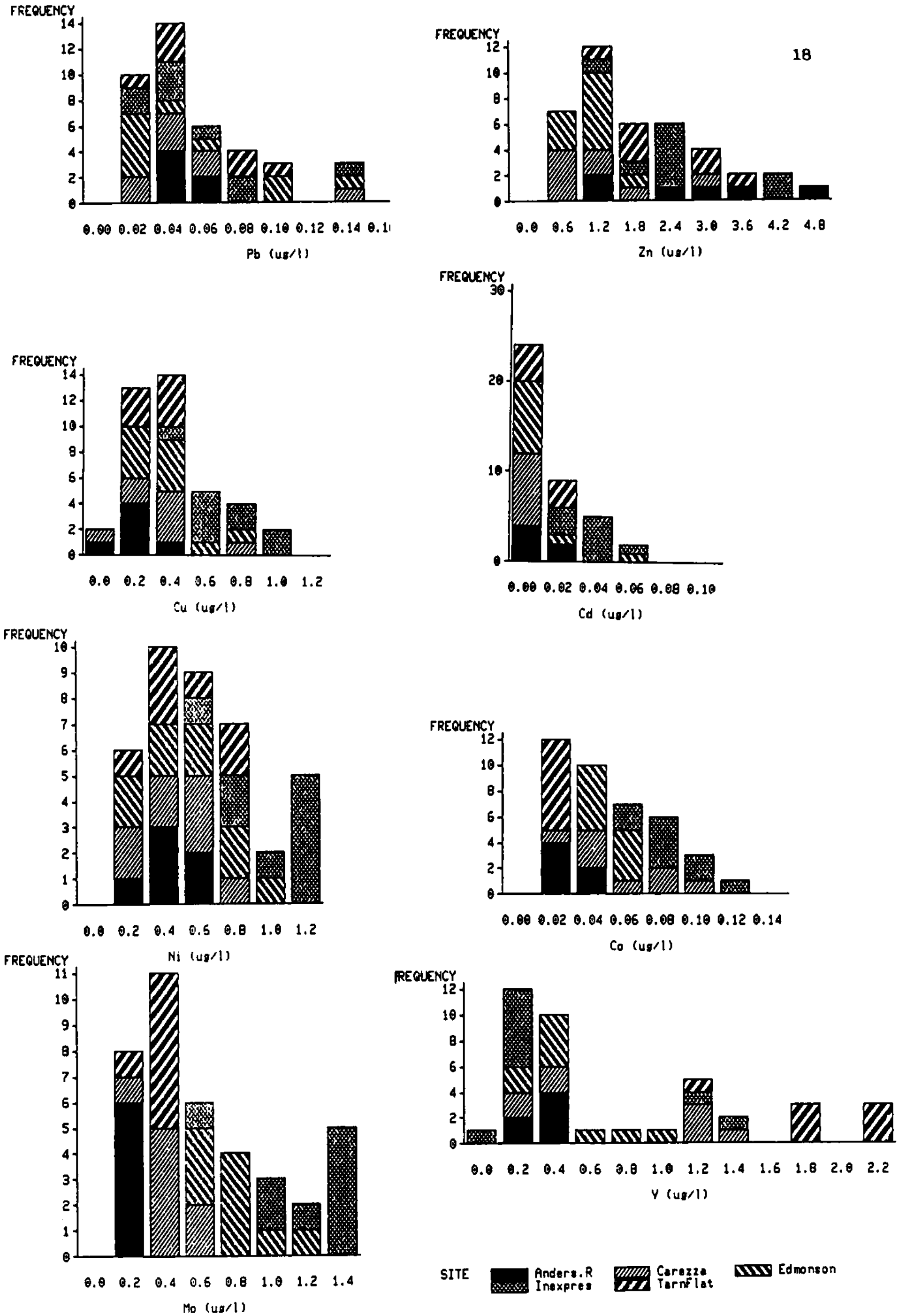

Figure 8 Frequency histogram for Ni, Mo, Co, V., Cd, Pb, Zn e Cu.

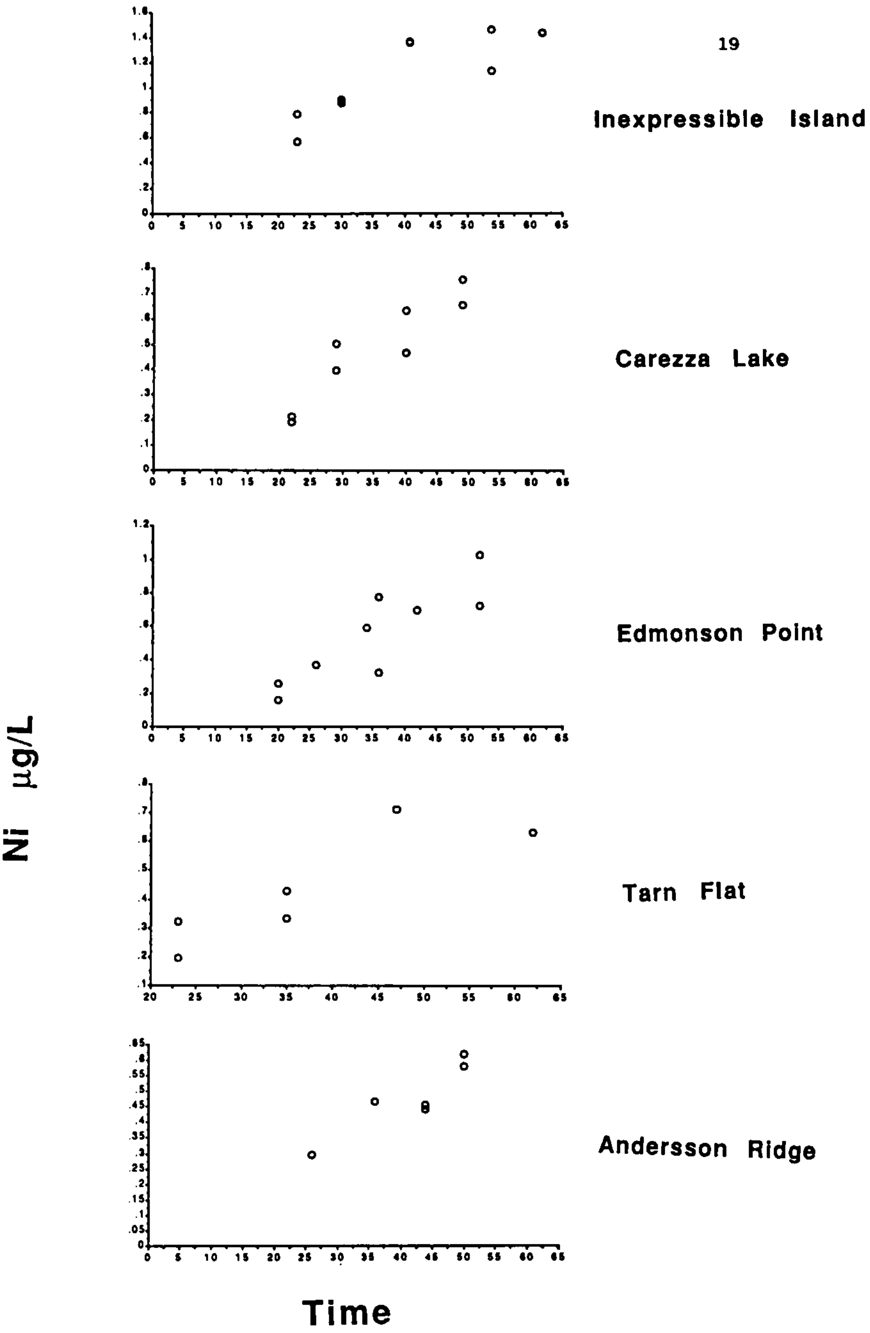

Figure 9 Ni-Time correlation. Time is expressed in number of days starting from December 1.

Differences in the trace metal content do not seem to be related to their background concentrations[5-7] in catchment rocks.

The concentration of cadmium, lead, cobalt, vanadium and molybdenum generally did not vary in the period studied, with the exception of Carezza lake, where an increase in the cobalt concentration was observed starting at the end of December and lasting until the beginning of January.

The nickel concentration increases regularly with time even in the lakes where no salinity increase occurred (Figure 9).

CONCLUSION

The analysis of the major constituents vs. time has not evidenced any significant variations in their ratios. This suggests that during the sampling period there were no substantial changes in contributions from salts of marine origin or from rock leaching.

When the trends of salinity in Carezza lake, based on the values obtained in the 1986–87 and 1987–88 campaigns,[1] are studied, their similarity to those evidenced during the present study (Figure 10) are evident.

One particularly interesting aspect concerns the repetition of the trends in composition over time. In fact, at the start of the summer season, when the surface ice starts shrinking, salinity is always far lower than that measured at the end of January when the lake surface again tends to be completely frozen. Moreover, the minimum and maximum salinity values found do not vary too much one from another. This fact would tend to exclude that the increase in salinity during the course of the same season is due to a large scale contribution of solutes from the basin surrounding the lake, because in the absence of variations in the lake water level and considering that small lakes are often devoid of any sizable inflows and

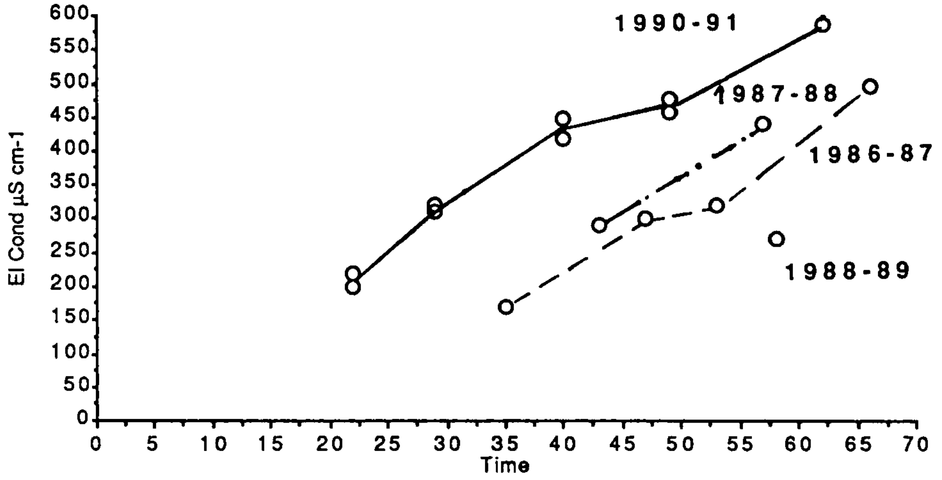

Figure 10 Electrical Conductivity-Time correlation in Carezza lake samples collected in different years. Time is expressed in number of days starting from December 1.

outflows, there should probably be a progressive average increase in salinity from one year to the next. The overall uniformity in the ratio between the main anions and cations over time could provide confirmation of this hypothesis.

Schmidt *et al.*[8] have studied the evolution of the physical and chemical characteristics of the water of two shallow ponds throughout the year at CAPE EVANS, ROSS ISLAND. They observed that the waters of the ponds became increasingly saline during freezing, with maximum conductivity in July. Calcium carbonate and sodium sulphate precipitated out of solution during early freezing.

For the lakes of Terra Nova Bay it may be supposed, in view of their relative proximity to Ross Island, that similar conditions to those observed by the above researchers could occur. It follows that during the successive, progressive remelting of the ice, in the absence of any phenomena of stratification, there should be a steady decrease in the salinity of the bottom waters. In the lakes studied, the maximum depth of which is about 3.5 m (Tarn Flat), the action of remixing the waters should be very limited all the time the surface layer is frozen and consequently, as emphasized by Vincent[9] and Heywood[10], there could be phenomena of stratification. When all the ice present is melted, the wind action should contribute towards a rapid homogenization of the lake waters.

For the present study, in which sampling was conducted near the shore, the chemical composition of the waters should be greatly influenced by the degree of homogenization of the water column. The ice cover, rather variable at the different sampling sites, should have conditioned the remixing processes in a differentiated manner. As has already been pointed out, the relative stability of the chemical composition of the Tarn Flat lakes, and subordinately of Andersson Ridge, with respect to the progressive increase in the salinity of the Carezza, Inexpressible Island and Edmonson Point lake, could be interpreted as a function of the rate of homogenization of the water column. However, the continuation of a salinity gradient between the surface and the bottom does not seem to be influenced, solely by the presence of ice on the lake surface, since Edmonson Point and Tarn Flat, both free of ice from the end of December, show different conductivity trends, steadily increasing in the first case and fairly constant in the other.

This bears out the continued stratification in the first lake and the homogenization that has occurred in the second one. On the other hand, Andersson Ridge which was never completely ice-free from end-December to end-January, showed slight changes in salinity, as opposed to Inexpressible Island and Carezza lake, which, remaining ice-free only in January, showed a clearcut increase in salt content during the observation period.

It is possible that the conditions were present for rapid remixing, at Tarn Flat, which is subject to more intense wind action, becomes ice-free earlier and, compared with the other lakes, receives a greater flow of water from the nearby glacier, whereas at Andersson Ridge, more than elsewhere, the conditions for maintaining a salinity gradient in the water column were present.

The trace elements—with the exception of Ni, for which an increased concentration over time is observed for all the lakes—generally show a content that varies very little over time, even where an increase in salinity has been observed. It follows that the trends of the concentrations of the major trace elements are conditioned by different processes.

Lack of information on the minerals and on the concentrations of trace metals in the solutions that form with the gradual formation of ice in the small lakes in Terra Nova Bay

Table 5 Saturation index [SI=ln(Q/K)]—Index values of > o and < o denote saturation and under-saturation, respectively.

Ref.n°	*Date*	*Cu*	*Malachit*	*CuO*	Cu_2O	$ZnCO_3$	*ZnO*	$ZnSO_4$	$PbCl_2$	$PbCO_3$	*PbO*	$PbSO_4$	V_2O_5	Pb_3VO_4
32	23/12/90	−7.6	−1.8	−0.81	−4.4	−4.2	−4.3	−15	−11	−4.2	−10	−7.5	−98	−54
32	23/01/91	−15	−4.8	−2.6	−14	−4.9	−6.3	−15	−10	−4.4	−12	−6.7	−89	−50
18	26/12/90	−8.1	−0.7	0.85	−3.1	−3.9	−2.2	−17	−16	−4.9	−8.9	−10	−105	−57
18	05/01/91	−6.4	−4.5	−1.9	−4.2	−4.1	−4.1	−16	−15	−4.8	−11	−8.7	−96	−53
30	20/12/90	−9.1	1.0	2.1	−2.8	−3.8	−1.1	−18	−17	−5.0	−7.6	−12	−112	−59
30	05/02/91	−11.6	0.01	0.82	−6.7	−3.4	−2.1	−17	−15	−4.3	−8.6	−11	−107	−57
46	23/12/90	−18	−3.2	−1.6	−15	−4.3	−5.0	−16	−13	−3.7	−11	−7.9	−92	−48
46	31/01/91	−16.3	−4.7	−2.4	−14	−4.6	−5.7	−16	−12	−3.8	−11.2	−7.2	−90	−49
7	22/12/90	−13.1	−0.9	−0.3	−8.6	−3.8	−3.1	−16	−15	−4.1	−9.2	−9.7	−102	−55
7	18/01/91	−16.4	−2.1	−0.3	−12	−3.4	−2.5	−16	−15	−4.3	−9.4	−10	−103	−56

make it difficult to establish the causes of the relative constancy of a number of trace elements in the waters studied during the austral summer.

In assessing the available data, in order to indicate by way of hypothesis a possible explanation of what has been observed, the following considerations could be useful:

The study of the saturation indices (obtained with SOLMINEQ) for Cu, Zn, Pb and V (Table 5) shows that these elements are undersaturated with respect to some of their minerals, so that it appears hardly likely that the constancy of their concentrations is controlled by the equilibrium with the minerals considered. Due to the positive Eh values of the studied samples the equilibrium with sulphides cannot be taken into account.

The Cu, Zn, Pb, Co and Ni contents in the sediments collected near the shores of Carezza lake are very similar to those contained in the fine soil fraction [11].

If this were also to be confirmed for the sediments in the deepest parts of the lake, the possibility of minerals containing trace elements accumulating during the gradual freezing of the water in the lakes could be excluded. In fact, if precipitation of the of the minerals were to occur, there would be a rapid redissolving of the same during the remelting phase of the ice. In this phase, control of the concentrations of trace metals in solution could be regulated by the balance with their own minerals. In such a case, similarly to what happens for the major components, a concentration gradient would be established in the water column during the remelting phase. The results obtained, with the exception of Ni, would appear to exclude this possibility since the concentration of the other trace elements undergoes fairly limited variations.

From what has been stated, and the fact that during the warm period there is intense algal activity in the Terra Nova Bay lakes, which could produce an uptake of trace elements, the complexity of the processes that determine the solubilization or the removal of trace elements from the waters, becomes evident and so the scarce variability over time of the concentration of a number of heavy metals could be the result of the dynamic equilibrium between the two processes mentioned. However, the data available are not sufficient to provide exhaustive answers on the processes that condition the chemical composition of the Terra Nova Bay lakes, and further research will be necessary to achieve this aim.

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