solved in the sea water diffuses into the oxygen-deficient stale air. Before being discharged, the sea water passes through the baffled tank where entrained air is recovered. The scrubbed air, recharged with oxygen, is returned to the combustion chamber where it is again used by a flame or by a laboratory animal. The oxygen concentrations of the streams of air entering and leaving the chamber are continuously measured with a pair of oxygen analyzers (Beckman Model 777).

A microburner consuming only the oxygen confined within the apparatus burned for 31 minutes (Fig. 2). When aerated sea water was supplied at a rate of 30 liter/min, the flow of water forced the air to circulate rapidly through the apparatus. The concentration of oxygen in the air immediately began to increase. The increase having been demonstrated, the return to atmospheric concentration was hastened by briefly venting the system to the atmosphere, and the burner was again lighted. The flame burned for a period of 4 hours and 15 minutes and was then intentionally extinguished. All indications were that it would otherwise have continued to burn indefinitely.

An experiment with two small rats demonstrated that the air in the habitation chamber could sustain life. In one of these experiments the rats were maintained in the chamber for 8 hours without apparent discomfort. They were examined 2 weeks later and were in good health.

In the foregoing experiments, oxygen was recovered from the sea water and was supplied to the rats (or to the flame) at a rate of approximately 0.1 liter/min. A scuba diver resting in an undersea shelter might, if he had been working strenuously, require an oxygen supply 30 times greater than that; a supply only 5 to 10 times greater should more than satisfy his average needs.

A venturi gas exchanger, operating at the same efficiency as the gas exchanger described, would probably have to process 200 to 300 liters of airsaturated sea water per minute to supply one diver with oxygen. To depths of approximately 20 m, sea water can be pumped economically (1 to 3 hp per man) at such rates with conventional pumps, but at greater depths an energy-conserving pumping system (7) is required.

The maximum concentration of oxygen that can be maintained in a cham-

ber ventilated by means of a sea-water scrubbing process is limited by the amount of oxygen dissolved in the water and the rate at which the water is processed and the oxygen is consumed (Fig. 3). Similarly, the limit of control of carbon dioxide is restricted by the absorbing capacity of sea water and the rate at which the water is processed and carbon dioxide is produced. Actual operating levels should not be much different from the theoretical limits, since scrubbers are very efficient.

The apparatus described was not designed to function underwater. Pressures were essentially uniform throughout the apparatus and were approximately equal to that of the atmosphere. Different pressures will be required in the various compartments of similar apparatus designed to function underwater.

The pressure in an underwater gas exchanger (as distinguished from a habitation chamber) must not exceed 1 atm owing to the fact that, since sea water and air are in contact only at the ocean surface, the total pressure of dissolved gases in sea water is approximately 1 atm at all depths. If air and sea water were brought together in the gas exchanger at pressures greater than 1 atm, more air would dissolve into the sea water than would diffuse from it, and the net amount of air in the system would decrease.

A net gain in the amount of air in the system could be achieved by maintaining a partial vacuum in the gas exchanger. Air lost as fine bubbles in the exhaust sea water (or air used for such purposes as operating air locks and charging scuba tanks) could thereby be replaced. Removal of carbon dioxide would be less efficient but, nevertheless, would be adequate if the vacuum did not exceed about 1/3 atm.

For efficient recovery of oxygen, pressure in the habitation chamber must be greater (preferably several times greater), than 1 atm. Since the purpose of the scrubbing process is to strip fresh air from sea water with stale air, the lower the oxygen concentration of the stripping air, the more efficient the process. The oxygen concentration of the air in a pressurized habitation chamber can be "breathed down" to relatively low levels (Fig. 3), thereby aiding efficient recovery of oxygen from the sea water.

The interior of the gas exchanger

of new apparatus under construction at NCEL will be maintained under a slight vacuum and the habitation or combustion chamber will be slightly pressurized. The apparatus will be tested while submerged.

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23 May 1966

A Chemically Stratified

Lake in Alaska

Abstract. A meromictic (chemically stratified) lake occupies a thawed depression in a pingo in interior Alaska, near Circle City. Increased salt concentration and anaerobic conditions characterize the zone extending from a maximum depth of 3 to 8.8 meters. The concentration of strontium and lithium is unusually high for lake water.

Meromictic lakes offer unique systems for studies in limnology and geochemistry because of their permanent chemical stratification and incomplete



Fig. 1. Pingo Lake in July 1965. The surface bloom of Cladophora sp. was unusual for lakes in this part of Alaska.

mixing. Recently, three lakes in interior Alaska were found to be meromictic; two are in the Tanana River Valley near Northway, and one, Pingo Lake (65°40'N, 144°20'W), is in the Birch Creek drainage near Circle City. Before the discovery of these lakes, only 17 lakes with meromictic characteristics had been reported in North America (1).

Table 1. Some chemical characterists of Pingo Lake, Alaska.

Depth (m)	$p\mathbf{H}$	Solids* (mg/liter)	Ions (mg/liter)								
			Ca	Mg	K	Na	Sr	Li	HCO ₃	C 1	SO ₄
5 July 1964											
0	8.2	2240	49	137	20.5	385	1.20	0.77	464	172	1050
4	8.0	3040	62	170	28.5	501	1.35	1.08	636	221	
8	7.9	3020	62	184	29.0	519	1.35	1.07	637	222	1440
23 July 1965											
0	8.13	2420	113	150	25	460	1.64	0.92	497	188	
2	7.52	2790	140	164	27	510	1.80	0.97	578	204	
3	7.39	3010	154	174	30	540	1.87	1.02	676	218	
4	7.38	2950	170	172	30	520	1.94	1.07	703	233	
6	7.40	2970	153	172	29	540	1.96	1.07	712	223	
8	7.39	2960	152	180	30	540	1.97	1.08	705	222	
21 August 1965											
0		2490	94	156	30	480	1.58	0.92		189	
2		2750	132	168	30	470	1.82	1.02		207	
3		2960	147	172	31	560	1.96	1.06		220	
4		2960	152	172	30	560	1.96	1.07		222	
6		2970	154	176	30	560	1.97	1.07		223	
8		2990	154	176	33	560	1.97	1.08		220	

* Total dissolved solids.



Fig. 2. Contour map of the pingo and enclosed lake basin. Pingo Lake is shown by the shaded area. The contour intervals are in meters above sea level.

Pingo Lake (Fig. 1) apparently originated in the thawed crater of a pingo (2). Pingos (3) in this area are formed when water, rising by hydraulic pressure through gaps in the permafrost, freezes and uplifts a mound of ice covered by a thin layer of alluvium (4). The overburden at the top of a pingo is usually ruptured during this process. The melting ice may form a thaw lake. The age of Pingo Lake is unknown, but Krinsley (2, 5) has dated (C^{14}) organic material in the overburden and found it to be at least 5720 ± 65 years old. The lake has a surface area of 2.4 ha and a maximum depth of 8.8 m. The average depth is 4.47 m; the maximum length, 205 m; the maximum width, 165 m; the volume, 1.09×10^5 m³; and the length of the shoreline, 563 m (Fig. 2).

Subsurface springs probably deliver water to the crater of this pingo, as the lake has essentially no drainage area; yet a small volume of water is continuously lost through the outlet. Moreover, subsurface aquifers are characteristic of this type of pingo (4). When subaquatic springs introduce saline or dense water into the depths of a lake, a permanent stratification in density may result. The absence of complete circulation, because of vertical density differences brought about in this way, has been termed crenogenic meromixis (6).

The possibility of meromixis in Pingo Lake was first suggested by the analysis of water samples collected on 5 July 1964. Additional physicochemical data were obtained on 23 July and 21 August 1965. These results indicated that the lake is chemically stratified (Tables 1 and 2). In addition, both temperature and conductivity profiles (Fig. 3), show strong vertical stratification near the beginning and end of the ice-free season (7), which also would indicate that mixing is incomplete.

The chemical and thermal stratification in Pingo Lake suggest considerable stability. Probably the wind has only a slight effect in mixing this small lake, owing to the fact that the lake is sheltered from the wind by forest vegetation (*Picea mariana* and *Picea glauca*) (Fig. 1), and by the rim of the pingo which projects 5 to 6 m above the surface of the water (Fig. 2).

The chemical nature of the water in Pingo Lake is distinctly unusual (Table 1). The values of strontium and lithium may represent some of the

Table 2. Dissolved oxygen and hydrogen sulfide in Pingo Lake, Alaska on 23 July 1965.

Depth (m)	O ₂ (ppm)	H ₂ S (ppm)		
0	11.1			
2	1.7	0		
3	0	0		
4	0	>5		
6	0	>10		
8		>20		

Table 3. Concentration (mg/liter) of various substances in spring and well water near Pingo Lake, Alaska.

Ion	Arctic Hot S	Circle City well water	
Ca	29*	18.9	87.5
Mg	2.1*	0.3	23.6
ĸ	8.6*	10.8	2.0
Na	248*	260	5.6
HCO ₃	173*	190	399
C1	252*	246	3.
So4	98*		
H_2S		2-5	0
	Total diss	ds	
	816*	878	277

* Values posted at Arctic Circle Hot Springs by John Berdahl.

highest values recorded for lake water (6, 8). The fact that lithium is a common constituent in the water of mineral springs (6) supports the suggestion that the meromixis in Pingo Lake is maintained by crenogenic factors. The discrepancy in calcium content between 1964 and 1965 is thought to have been the result of biological activity or faulty analysis in 1964. Mostly constant values for the other ions, particularly below 3 m, were observed on all three dates.



Fig. 3. Temperature (--) and conductivity (----) profiles in Pingo Lake. 19 AUGUST 1966

One of the most common features of meromixis is an absence of dissolved oxygen and the presence of hydrogen sulfide in the deep waters (1). Such a condition is well developed in Pingo Lake (Table 2). Although this environment may be highly toxic to organisms, specialized biological communities may develop. For example, the larvae of the midge, Chaoborus sp., were found in abundance in Pingo Lake and might be expected to inhabit the deeper zones (9). Anaerobic bacteria also are common components of this community.

It is interesting to compare the chemical compositions of Pingo Lake with well water at Circle City (20 km northeast), and spring water at Arctic Circle Hot Springs (25 km south). Some of the more important chemical constituents are given in Table 3. On the basis of the ions found to be most abundant, the water in Pingo Lake can be classified as a sodium sulfate type, whereas that of Arctic Circle Hot Springs is predominately a sodium chloride type, and well water from Circle City is a calcium carbonate type.

Pingo Lake differs markedly from nearby lakes; the basin is deeper and the water contains more dissolved solids. The discovery of permanent chemical stratification and the associated biological zonation now provides an opportunity to study these phenomena in a subarctic environment (10). G. E. LIKENS

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Electrolytic Dissolution of Iron Meteorites

Abstract. When iron meteorites are dissolved anodically in neutral solution, nonmetallic inclusions are not attached and collect at the bottom of the anode compartment. When the meteorites contain both kamacite and taenite, the kamacite dissolves preferentially, revealing a three-dimensional Widmanstätten pattern.

The true chemical composition of nonmetallic inclusions in iron meteorites is difficult to establish with certainty by the usual chemical techniques. Many nonmetallic substances common to iron meteorites are completely destroyed or largely altered by acid attack during the dissolution process.

Metallic meteorites are composed primarily of iron-nickel alloys containing small amounts of cobalt, phosphorus, sulfur, and carbon. Meteorites with less than 6 percent nickel (by weight) contain a single metallic phase: kamacite. If the nickel content lies between 6 and 27 percent two metallic phases usually result: kamacite, containing 5.5 percent nickel (alpha phase), and taenite, containing 27 to 65 percent nickel (gamma phase). Meteorites containing more than 27 percent nickel have only the single-phase taenite. The orientation of the thick bands of kamacite and thin plates of taenite parallel with octahedral planes results in the familiar Widmanstätten structure (1).

Common nonmetallic inclusions in iron meteorites are schreibersite [(Fe,Ni)₃P], troilite (FeS), daubreelite (FeCr₂S₄), cohenite (Fe₃C), graphite (C), and sometimes the silicate minerals enstatite [(Mg,Fe)SiO₃] and olivine $[(Mg,Fe)_2SiO_4]$ (2).

Inclusions in steel, especially carbides, have been successfully extracted by an electrolytic technique (3); the steel sample was made the anode and dissolved electrolytically in an electrolyte such as 5-percent citrate solution adjusted to pH 5.0 to eliminate acid attack; nonmetallic inclusions fell to the bottom of the anode compartment and were collected by filtration. Electrolytic dissolution of iron meteorites containing both kamacite and taenite phases results in preferential attack on the kamacite, revealing a three-dimensional Widmanstätten pattern as well as separating the nonmetallic inclusions.

We now describe electrolytic dissolution of iron meteorites and separa-