fracting planes are permuted identifies the Burgers vectors of these dislocations as $(a_0/3)\ \langle 11\bar{2}0\rangle$ type. In Fig. 1 only two-thirds of all the dislocations appear since the $\pm$ $[\bar{2}110]$ directions vanish with $(01\bar{1}0)$ diffracting planes. The screw orientation is most common, and many dislocations are very nearly straight in the screw orientation. This suggests either a much higher mobility for edge and mixed orientations or a very low energy (Peierls valley) for the screw orientation.

Some cross slip of $\langle 11\bar{2}0\rangle$type dislocations on pyramidal planes of $\{hh01\}$ type, probably, but not necessarily exclusively, $[1\bar{1}01]$ type, is evident at the right hand side of Fig. 1 where some short parallel segments remain of a configuration that has expanded from a source. Some of these dislocations are still attached to screw segments extending out from the source. Others have lost their screw segments by gliding out through the crystal surfaces and remain as short segments threading through the crystal.

Some conclusions that can be drawn from our preliminary observations such as the example described above are:

1) Growth of ice dendrites does not require a dislocation mechanism and nearly dislocation-free crystals can be formed. In some cases dendrite branches have grown together without dislocation formation.

2) The Burgers vectors of dislocations formed by light strain lie in $\langle 11\bar{2}0\rangle$ directions.

3) The basal plane (0001) is the principal slip plane although $\langle 11\bar{2}0\rangle$ type dislocations also cross slip on pyramidal planes, probably $\{1\bar{1}01\}$.

4) The screw orientation is strongly preferred in the basal plane.

5) Dislocation reactions of the type $(a_0/3)\ [11\bar{2}0] + (a_0/3)\ [1\bar{2}10] = (a_0/3)\ [2\bar{1}\bar{1}0]$ are observed.

6) Prismatic punching occasionally originates at the same growth defects from which basal glide dislocations multiply. The presence alone of $\langle 11\bar{2}0\rangle$ type dislocations indicates that basal glide would predominate in macroscopic plastic flow and that dislocation pile-ups would readily nucleate cracks.

These dislocation properties appear to account for the observed plastic anisotropy and brittleness of ice. However, slip by other dislocations with nonbasal Burgers vectors has not been excluded although not observed in these experiments. Etch pit patterns on (0001) surfaces (*5*) show only a small fraction of the dislocations structure visible in diffraction topographs since dislocations tend to lie parallel with (0001) planes.

Dislocation configurations in hexagonal substances with such diverse properties as zinc (*6*) and silicon carbide (*7*) are observed to be remarkably similar to those in ice. Although the temperatures at which the structures form are radically different, they are, in each case, close to the respective melting temperature.

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## Reversibility of Reaction of Potassium with Liquid Ammonia

Abstract. *Ammoniated electrons exist in solutions of potassium amide in liquid ammonia which have reached thermodynamic equilibrium with hydrogen gas. By determining electron concentrations by electron spin resonance, an equilibrium constant of $10^5$ at room temperature has been obtained.*

The correlation of thermodynamic data for electrolytes in liquid ammonia (*1*) made it possible to estimate an equilibrium constant of approximately $10^6$ at 25°C for the reaction of the ammoniacal electron ($e^-_{am}$) with ammonia to form amide and hydrogen:

$$e^-_{am} + NH_3 = NH_2^- + \tfrac{1}{2}\ H_2$$

It was recognized that this equilibrium constant is probably small enough to permit direct measurement of the equilibrium; by using electron spin resonance (ESR), we have recently detected unpaired electrons in potassium amide solutions which were equilibrated with hydrogen partial pressures as low as 0.1 atm.

Measured amounts of potassium metal and ammonia were sealed in Pyrex glass tubes (4 mm × 20 cm), and the tubes were allowed to stand at room temperature. Several days after the deep blue color of the potassium solutions had been replaced by the yellow color of the potassium amide solutions, distinct ESR spectra were observed with a Varian V-4502 EPR spectrometer. The spectra were single resonances of very narrow half-width (~0.06 gauss) with a Landé $g$-value of 2.0010; the close agreement of these parameters with those observed by Hutchison and Pastor (*2*) for potassium solutions makes it certain that the spectra correspond to the ammoniacal electron. Several data indicate that true equilibrium was achieved. (i) The intensities of the spectra of solutions kept at room temperature did not change during periods as long as 3 months. (ii) Raising the temperature of a solution caused the electron concentration to increase, and cooling caused the electron concentration to decrease (*3*). After returning a solution to room temperature, the electron concentration returned to its original value in a period of about 1 day. (iii) A tube fitted with break-seals containing an equilibrated solution was opened, and most of the hydrogen was removed. After re-equilibration, a markedly weaker ESR signal

Table 1. Equilibrium data for ammonia solutions at room temperature.

| Concn. of amide ion ($M$) | $P_{H_2}$ (atm) | Concn. of electron ($10^{-5}\,M$) | $\frac{P_{H_2}{}^{1/2}(NH_2^-)}{(e^-)} \times 10^{-5}$ |
|---|---|---|---|
| 0.50 | 23.2 | 0.54 | 4.5 |
| .57 | 11.9 | .42 | 4.7 |
| .81 | 28.5 | .52 | 8.3 |
| .99 | 19.6 | .52 | 8.4 |
| 1.26 | 27.1 | .56 | 12 |
| 1.56 | 23.2 | .46 | 16 |

was observed. Hydrogen gas was then put back into the tube, and, after another equilibration, a stronger ESR signal was observed.

The data for five runs at room temperature are presented in Table 1 (*4*). The equilibrium quotient tabulated in the fourth column of the table increases with increasing concentration of amide ion. We would not have predicted this trend with amide concentration. Indeed, because we believed that the ratio of the activity coefficients for the amide ion and the electron would be relatively independent of ionic strength, we expected the equilibrium quotient to be independent of the potassium amide concentration. Perhaps the ESR signals (and hence the calculated electron concentrations) were too low by a factor due to dielectric loss that increased with increasing electrolyte concentration. As the electrical conductivity of a solution in an ESR cavity increases, the dielectric loss increases, and consequently both the cavity $Q$ and the instrument sensitivity decrease. Our results would be explicable if, as the potassium amide concentration increased, the instrument sensitivity for the ammoniacal electron decreased more rapidly than that for the reference sample of diphenylpicrylhydrazyl (which was located in a different part of the cavity). If the trend in equilibrium quotient is caused by either an unusual activity coefficient trend or a dielectric loss phenomenon, extrapolation of the quotient to zero concentration should yield an approximation to the equilibrium constant. Our data extrapolate to an equilibrium constant of approximately $10^5$, a value in fair agreement with the previously estimated value.

A rough optical absorption spectrum was obtained for a $0.5M$ potassium amide solution equilibrated for 45 days with hydrogen at approximately 10 atm pressure in a glass tube of 11 mm diameter. In the 6000 to 10,000-Å region, the solution showed the gradually increasing absorption characteristic of the short-wavelength tail of the 15,000-Å absorption band of the ammoniacal electron. Measurements at longer wavelengths were precluded by strong absorption by the ammonia.

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4. The concentration of amide ion was calculated from the weight of potassium and the volume of the solution. The hydrogen pressure was calculated from the weight of potassium and the volumes of the liquid and gas spaces, the solubility of hydrogen in liquid ammonia (*5*) being taken into account. The electron concentration was determined by indirectly comparing the signal with that of a benzene solution of recrystallized vanadium (IV) oxyacetylacetonate of known concentration. A sample of solid diphenylpicrylhydrazyl fixed in the sample cavity was used as an intermediate standard of comparison.
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## Radiocarbon and Soil Evidence of Former Forest in the Southern Canadian Tundra

Abstract. *Radiocarbon dating of charcoal on podzols along a transect reaching 280 kilometers north of the present tree line from Ennadai Lake indicates that former forests were burnt about 3500 years ago and again about 900 years ago. These forests probably were associated with periods of relatively mild climate.*

The tree line in central Canada marks a major discontinuity in vegetation, physiography, and culture. Northward across this boundary, rather continuous forest gives way to tundra vegetation, and string bogs are replaced by patterned ground. Chipewyan Indians live in the forest, and until recently Caribou Eskimos occupied the tundra close to the forest. From July through October the tree line coincides with the average position of the northern edge of the Arctic frontal zone; from November through February it marks the southern edge of this zone (*1*). It is thus the climatic boundary between Arctic air on the north and air-masses of Pacific or continental origin on the south. Former changes in the position of the tree line therefore can be expected to have had biotic, physiographic, cultural, and climatic consequences. In this report we present evidence of forests at least 280 km north of the present tree line about 3500 years ago and at least 90 km north about 900 years ago; we conclude that those were times of relatively mild climate.

The northern edge of continuous forest, which now crosses Ennadai Lake at about 60°45′N, 101°W, has the same general characteristics as when it was first described in 1896 (*2*)—black and white spruce (*Picea mariana* and *P. glauca*) are the dominant trees, the latter being less abundant and growing chiefly on special habitats (Fig. 1). At the north end of Ennadai Lake, tundra plants of southern Arctic affinities are dominant, although widely scattered clumps of white spruce are found on sheltered or otherwise favorable sites. Black spruce in these clumps reproduces primarily by layering, in contrast with its reproduction by seed in the forest. The transition from forest to tundra is quite sharp in this area, occurring within a distance of about 20 km (*3*). North of Dimma Lake, only black-spruce clumps are found, and north of Dubawnt Lake no trees are found except for outliers in the Thelon Valley near 64°15′N, 103°30′W.

Buried soils and charcoal show that forests extended north of Ennadai Lake as far as Dubawnt Lake in postglacial time. One site with evidence of a former forest is at the lake shore in front of the Ennadai Aeradio Station, about 40 km north of the tree line. Here, at the edge of a large esker, a buried podzol indicative of a former forest is covered by a layer of charcoal under a layer of wind-blown sand derived from the esker (*4*). Tundra vegetation grows on the surface. Podzol and charcoal are similarly associated along an esker about 25 km south of the tree line at Birch Bay at the south end of Ennadai Lake. Charcoals from these sites show carbon-14 dates of A.D. 1070±180 and A.D. 1080±100, respectively (WIS-5 and WIS-6) (*5*). Charcoal in a similar charcoal-podzol profile at Dimma Lake, 100 km north of the tree line, has been dated at A.D. 810±90 (WIS-17).

There is evidence of a still older forest at Caribou Point, near the tree line on Ennadai Lake; in each of two successive layers, charcoal overlies pod-