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Silicates and Their Relation to the Water Masses of the Western Atlantic Ocean

by

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Several authors have discussed the value of using the distribution of silicate in the Atlantic Ocean to trace the movement of major water masses (Cooper 1952, Richards 1958, Metcalf 1969). During the last seven years we have made silicate observations in deep water off the East Coast of Greenland (Grant 1968), in an area to the southeast of the Newfoundland Banks (Mann et al 1965), and along the 30°W meridian from the Equator to South Georgia. Using this data and data from Atlantis II (Metcalf 1969) a meridional section of the silicate distribution in the western banks of the Atlantic has been constructed. Comparison of this distribution with the distributions of salinity and temperature show that silicate is a useful trace for Antarctic Bottom Water and the Overflow Water passing through the Denmark Strait. It may also be a useful trace for the movement of Antarctic Intermediate Water.

Silicate determinations were made as part of normal hydrographic casts with teflon coated Knudsen bottles. The silicates concentrations in the North Atlantic were determined by the 'yellow' method of Grasshoff (1964) on board ship. The silicates in the South Atlantic were determined using an auto-analyser (Coote et al 1971). A north/south section of silicate and salinity has been constructed through the western basins of the Atlantic using the stations shown in Fig. 1. Four prominent features of the silicate distribution are apparent (Fig. 2). In the South Atlantic, a tongue of high silicate stretches north from the Antarctic Convergence below the tongue of low salinity that marks the northward spreading of Antarctic Intermediate Water. Below this a tongue of low silicate stretches south coinciding with a high salinity tongue resulting from the movement of North Atlantic deep water south. Near the bottom an increase in silicate coincides with the decrease in salinity that results from the northward movement of Antarctic Bottom Water. At the northern extremity of the section a decrease in silicate near the bottom coincides with a decrease in salinity that results from the southerly flow of Overflow Water from the Denmark Strait (Mann 1970).

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The silicate maximum in the tongue of high silicate associated with the Antarctic Intermediate coincides with a weak temperature minimum (Fig. 3) that lies below the salinity minimum. Both the silicate maximum and temperature minimum can be traced back to the Antarctic Convergence. As the convergence is approached silicates at the maximum increase and temperatures at the minimum decrease as one would expect if the silicate maximum and temperature minimum were caused by the northerly movement of a layer of water from the convergence, where its initial silicate content and temperature were determined. The silicate content of the bottom water increases in the South Atlantic towards the south along with a decrease in salinity, in fact, the isopleths of the two quantities follow each other closely, at abyssal depths. This indicates that the silicate distribution is caused by the northward movement of bottom water from the Antarctic where it has a high silicate content (∿ 130 μg at/l). Stefansson has observed a very low silicate content (∿ 6 μg at/l) in the heavy overflow water that passes through the Denmark Strait. A series of sections made by Hudson in 1967 from the east coast of Greenland to the Reykjanes Ridge showed that the overflow water can be traced by its low silicate content (Fig. 4).

From these results it seems that a good description of the silicate distribution in the Atlantic would enable the spreading of Arctic and Antarctic bottom waters over the floors of the basins and the spreading of Antarctic Intermediate Water to be traced by the silicate distribution. Some of the features of isolated silicate observations also suggest that this may be the case. In the vicinity of the Southeast Newfoundland Ridge, we have consistently found bottom water with silicate concentrations less than 20 μg at/l on the ridge or to the south of it, and water with silicate concentrations above 30 μg at/l to the north of the Ridge (Fig. 5). This implies that bottom water from the Newfoundland Basin which originated as overflow water through the Denmark Strait passes over the Ridge into the North American Basin, and that near bottom water in the North American Basin moves north into the Newfoundland Basin. This exchange is also implied by Worthington's (1970) chart of salinity on the 1.9°C potential temperature surface. Also in Fig. 5, a weak silicate maximum occurs at a depth of ∿900 meters that could result from remnants of Antarctic Intermediate Water carried north by the Gulf Stream which passes through the section above the south side of the Southeast Newfoundland Ridge (Mann 1967). Further to the north, the observations along section bb' (Fig. 4) show a weak silicate maximum to the east of the Reykjanes Ridge at about 800 meters depth. Water from the Gulf Stream system is brought into this area by the North Atlantic Current and its branches and it is possible that the silicate maximum could be traced upstream to the Antarctic Intermediate Water if data were available. At the bottom of the northern parts of the basin east of the Mid-Atlantic Ridge, high silicate values have been observed (Fig. 4) that could result from the northerly movement of Antarctic Bottom Water through the eastern basins of the Atlantic.

In summary we have been able to find a good correlation between the silicate distribution in the Western Atlantic with the distributions of salinity and temperature that are used to trace the spreading of Intermediate, deep, and bottom waters from polar regions. This indicates that the silicate distribution below the surface layers is primarily determined by advection. The distribution appears to be dominated by the northerly movement of Antarctic Intermediate Water and Bottom Water with high silicate content and southerly movement of Overflow Water with low silicate concentrations. Charts of silicate concentration should be a good means of tracing the movement of these water masses.

REFERENCES

COOTE, A. R., I. W. DUEDAL, R. S. HILTZ (1971). Automatic Chemical Analysis at Sea. *Advances in Automated Analysis*. Vol. 2. Symposium Publications Ltd. (In press).

COOPER, L. H. N. (1952). Factors affecting the distribution of silicate in the North Atlantic Ocean and the formation of North Atlantic deep water. *J. mar. biol. Ass. U.K.*, 30, 511-526.

GRANT, A. B. (1968). Atlas of Oceanographic Sections, Davis Strait-Labrador Basin-Denmark Strait-Newfoundland Basin. AOL Rep. 68-5.

GRASSHOFF, K. (1964). On the determination of silica in sea water. *Deep-Sea Res.*, 11, 597-604.

MANN, C. R., A. B. GRANT, T. R. FOOTE (1965). Atlas of oceanographic sections, Northwest Atlantic Ocean. BIO Rep. 65-16.

MANN, C. R. (1967). The termination of the Gulf Stream and the begining of the North Atlantic Current. *Deep-Sea Res.*, 14, 337-359.

MANN, C. R. (1970). Temperature and salinity characteristics of the Denmark Strait overflow. *Deep-Sea Res.*, 16, 125-137.

METCALF, W. B. (1969). Dissolved silicate in the deep North Atlantic. *Deep-Sea Res.*, 16, 139-145.

STEFANSSON, U. (1968). Dissolved nutrients, oxygen and water masses in the Northern Irminger Sea. *Deep-Sea Res.*, 15, 541-575.

RICHARDS, F. A. (1958). Dissolved silicate and related properties of some western North Atlantic and Caribbean Waters. *J. mar. Res.*, 17, 449-465.

WORTHINGTON, L. V., W. R. WRIGHT (1970). North Atlantic Ocean Atlas of Potential Temperature and Salinity in Deep Water. Woods Hole Oceanographic Atlas Series, Vol. 2.

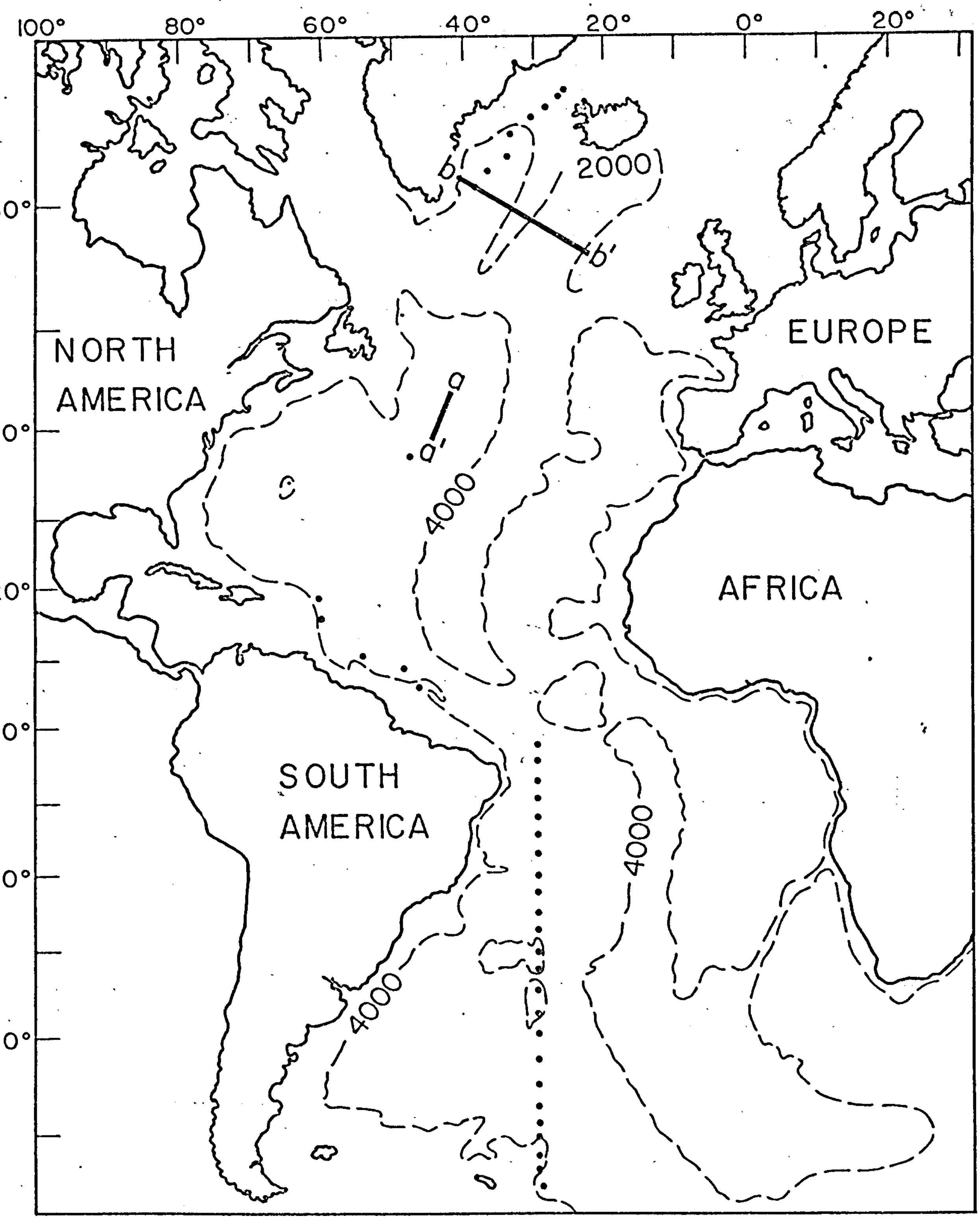

Fig. 1. Silicate stations in the Western Atlantic.

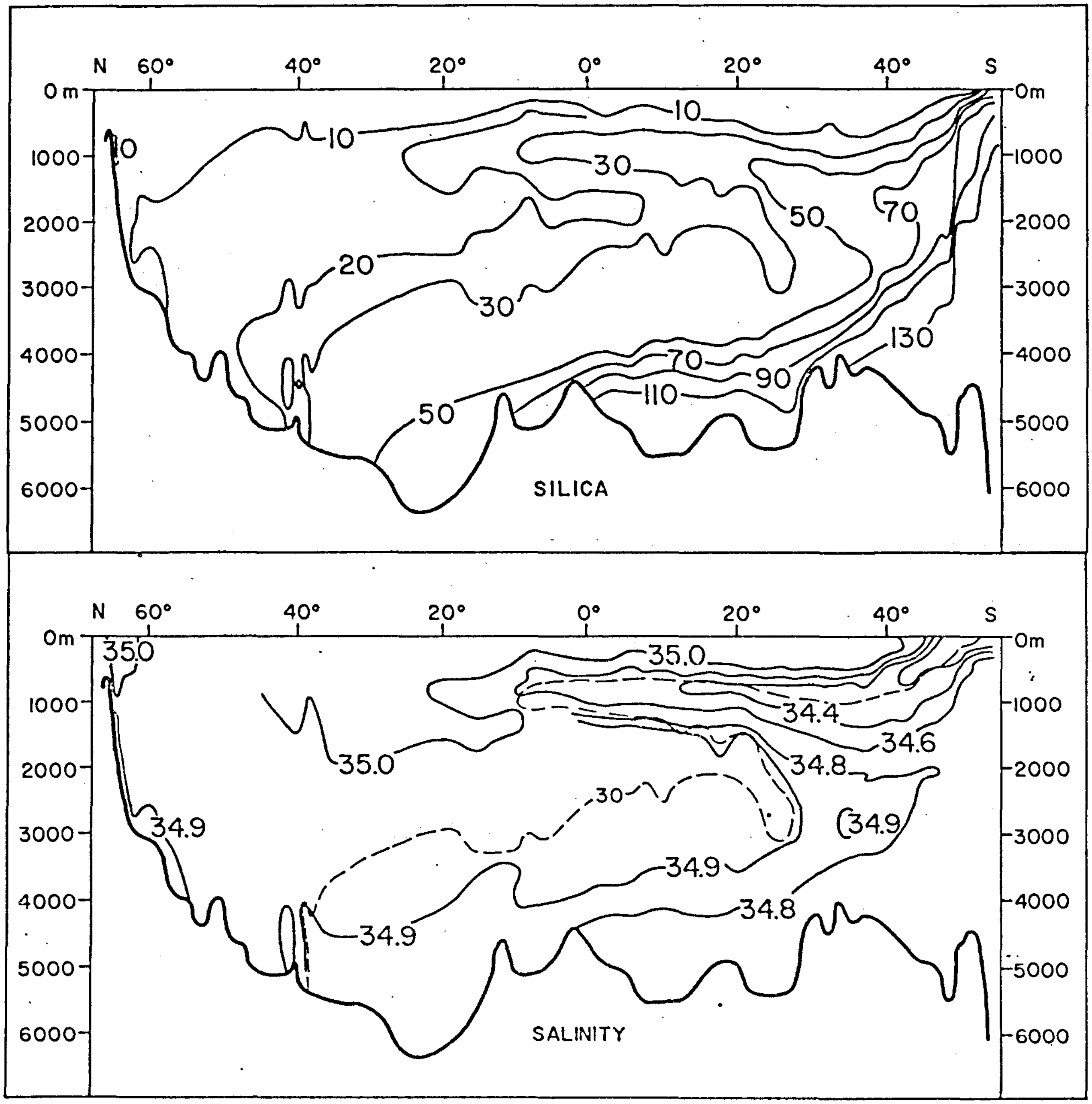

Fig. 2. Sections of silicate (μg at/l) and salinity (o/oo) through the western basins of the Atlantic Ocean.

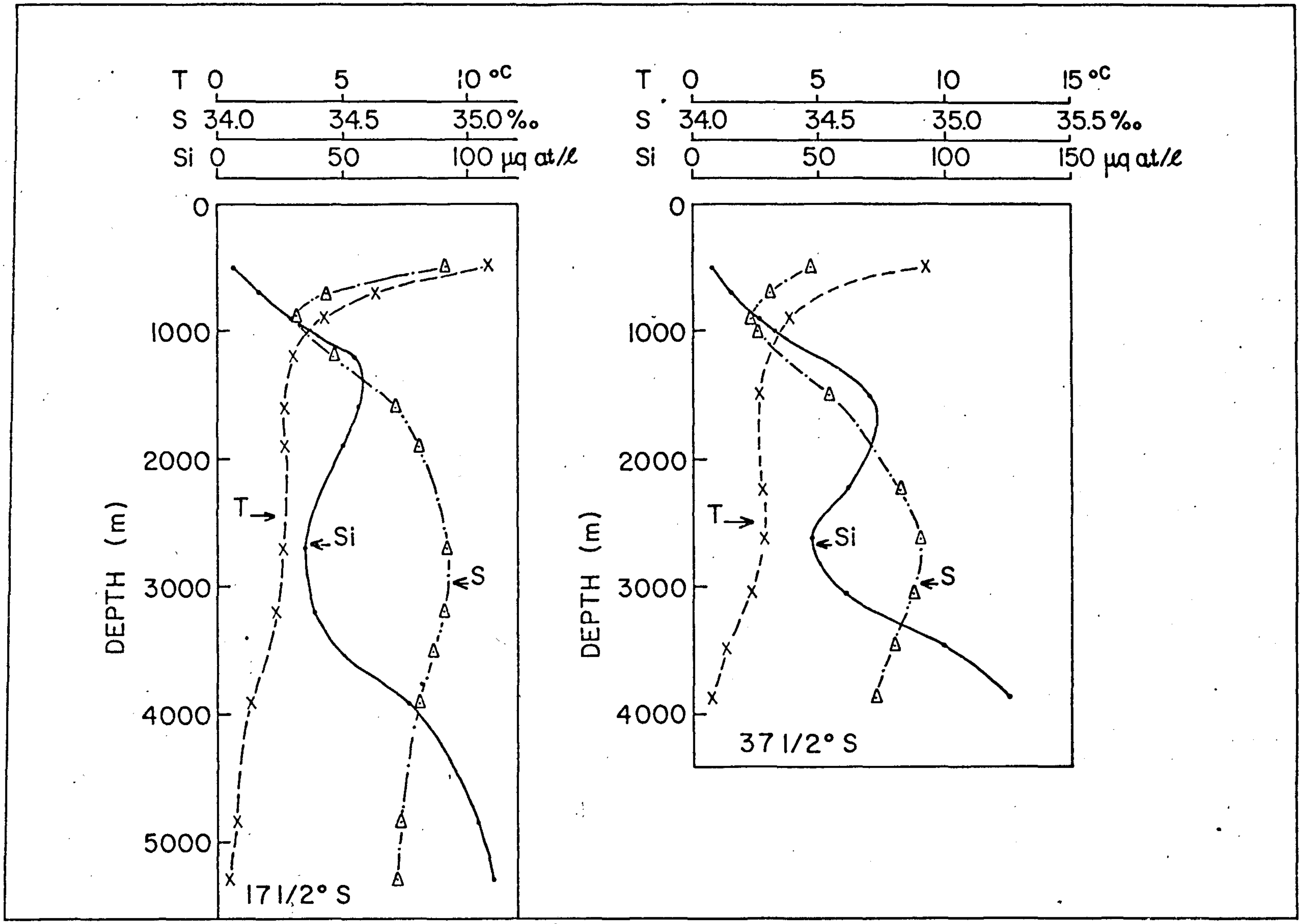

Fig. 3. Silicate, temperature, and salinity as a function of depth at selected stations in the South Atlantic.

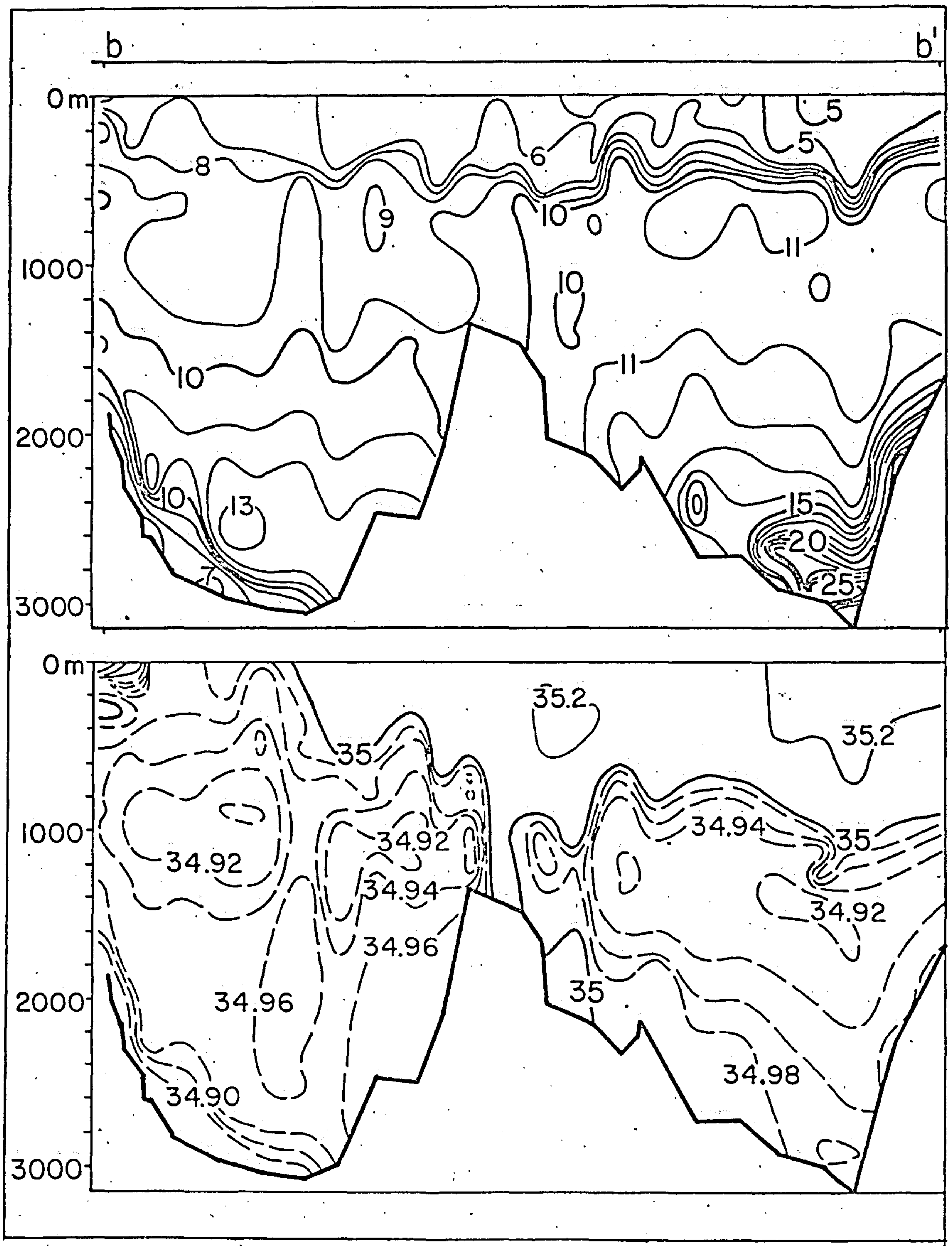

Fig. 4. Silica (μg at/l) and salinity (o/oo) for section bb' across the Reykjanes Ridge.

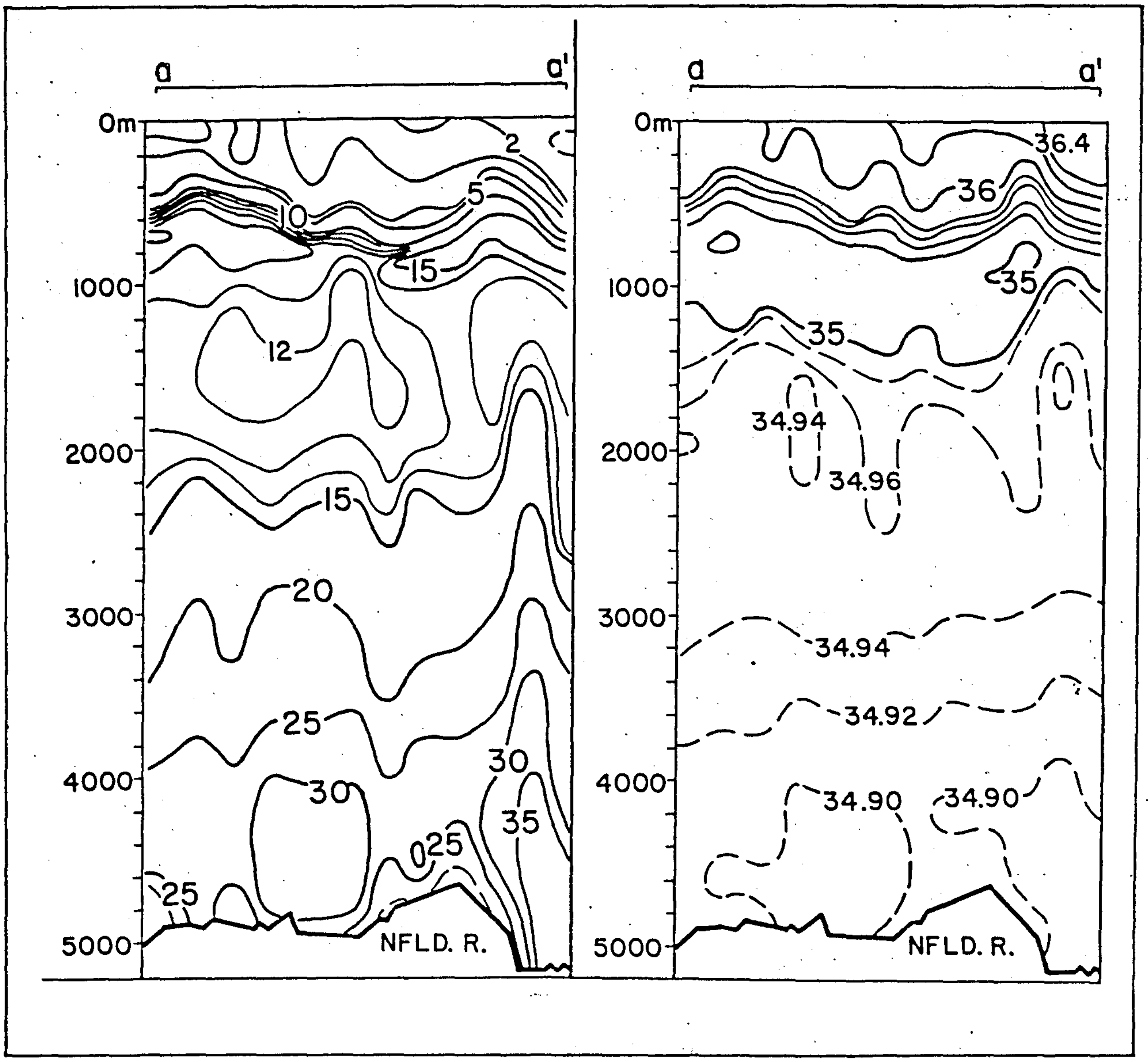

Fig. 5. Silicate (μg at/l) and salinity (o/oo) for section aa' across the Southeast Newfoundland Ridge.