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ON THE HYDROGRAPHY OF THE SHELF WATERS OFF MØRE AND HELGELAND

By

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INTRODUCTION

The coastal banks between Stad and Lofoten (Fig. 1) are an important spawning and hatching area for several fish species. The hydrography in this area is, however, insufficiently described, especially the conditions in winter and spring when the spawning and hatching of some of the most important commercial fish species take place.

The topography of the area is presented in Fig. 1. The extension of the shelf in this area is greater than off other parts of the Norwegian coast. In average the width is more than 100 nautical miles, except off Møre where the shelf is narrow.

Basic studies of the hydrography of the coastal banks were carried out by HELLAND-HANSEN and NANSEN (1909). Sea surface temperatures in the area were presented by EGGVIN (1966), and LJØEN (1962) discussed the hydrography in summer.

The present work presents a description of the general hydrography on the coastal banks in winter. The upper layers are dealt with in detail since their relationship with biological phenomena are of particular interest.

MATERIAL AND METHODS

The analysis is based on hydrographic observations made during two cruises. The first, in February 1956, covered the entire shelf and the adjacent deep sea between Grip and Lofoten (Fig. 5). The second, in early March 1968, covered the shelf between Stad and Frøyabanken (Fig. 7). At all stations observations were taken in standard depths to the bottom, and the temperature at 4 m depth was recorded continuously with thermograph.

Contribution given in honour of Gunnar Rollefsen at his 70th birthday.

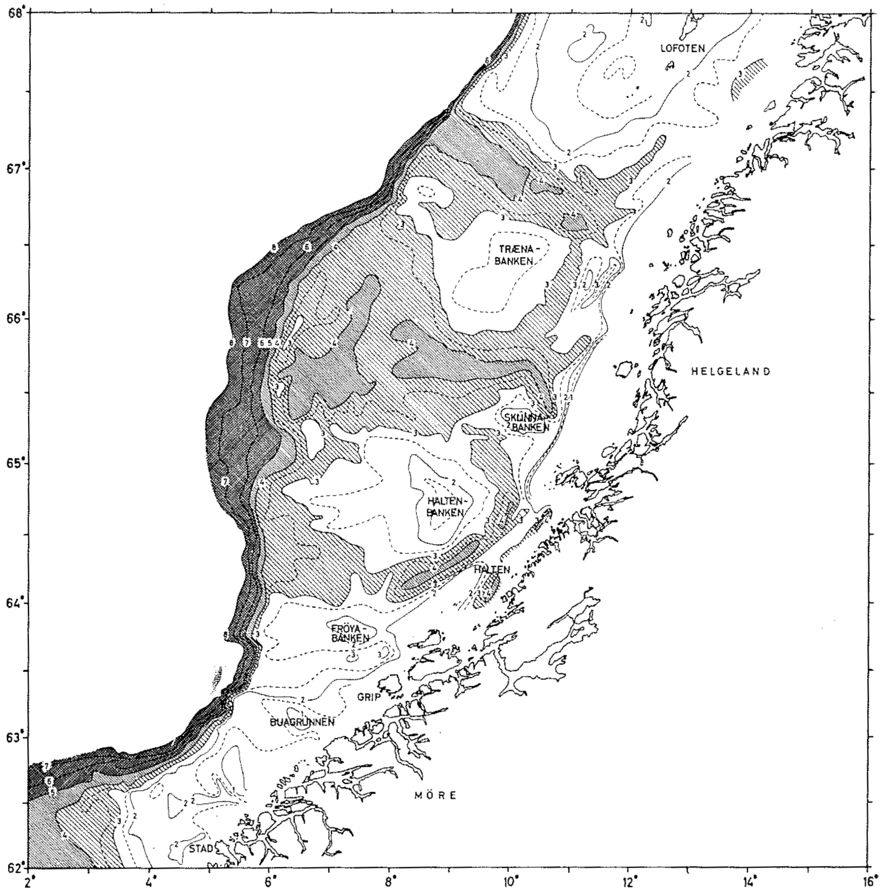

Fig. 1. Bathymetric map of the investigated area. Depths in hectometers.

THE WATER MASSES

Plots of temperature versus salinity from all points of observation are presented in Fig. 2, which gives a view of the different water masses in the investigated area. Three main water masses may be defined: Coast water, Atlantic water and Slope water. The latter is mainly a mixture of Atlantic water and the upper part of the deep water in the Norwegian Sea. The other two, Coast water and Atlantic water, are brought by the currents into the area where their characteristic parameters are altered due to mixing and heat exchange with the air.

Extreme Coast water is characterized by salinities and temperatures lower than 34.5‰ and 5.5°C. A_1 on Fig. 2 represents the core of Atlantic water of the Norwegian Atlantic Current in the southern part of the area. This water is partly protected from direct heat loss to the air by overlying

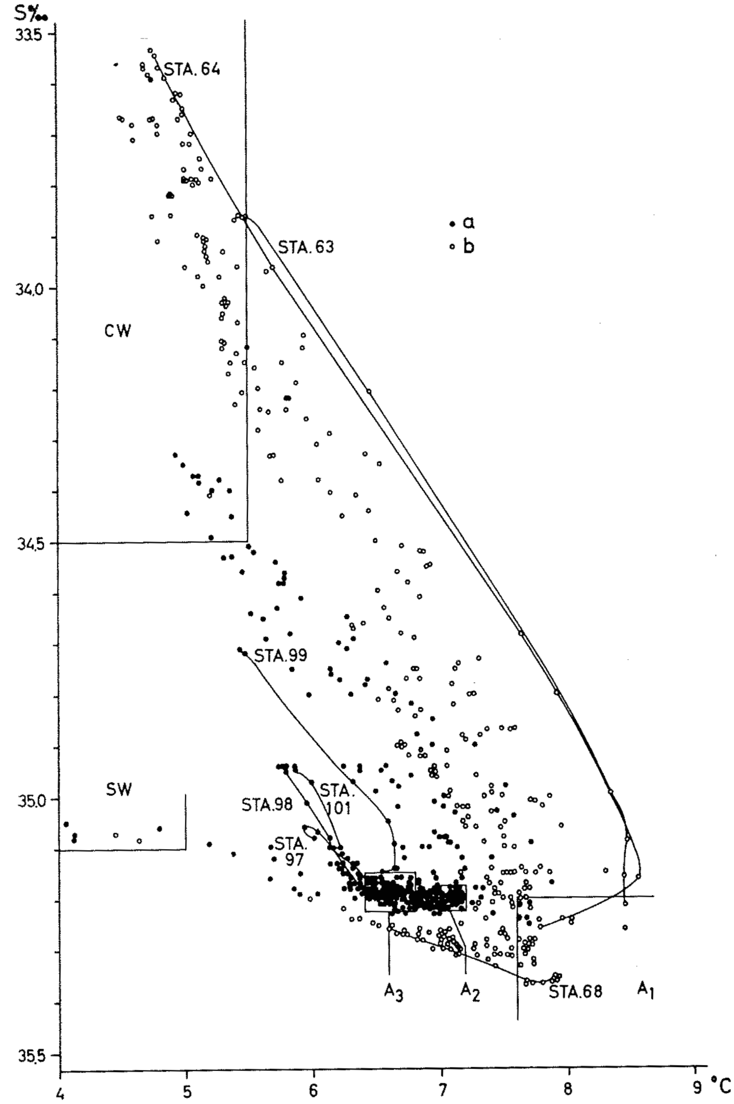

Fig. 2. Temperature–salinity diagram. (*a*) Observations in 1956. (*b*) Observations in 1968. CW: Coast water. SW: Slope water. A_1, A_2 and A_3: Phases of Atlantic water.

Coast water. A concentration of temperature–salinity points around 35.20‰ and 7.0–7.2°C indicates a larger bulk of nearly homogeneous water, A_2, a phase of Atlantic water. This water also gives the main contribution to a water mass, A_3, with salinities 35.15–35.22‰ and temperatures 6.4–6.8°C which have been formed mainly by cooling and a slight mixing with less saline water.

Slope water has salinities and temperatures below 35.10‰ and 5.0°C, and is located at the upper edge of the continental slope. There is no direct connection between Coast water and Slope water.

The temperature–salinity curves in Fig. 2 illustrate clearly that the extreme values of Coast water and Atlantic water are found in the southernmost part of the area. Corresponding to earlier findings (HELLAND-HANSEN and NANSEN 1909), both salinity and temperature of Coast water increase further north while the values in Atlantic water decrease. These changes are due to mixing between the water masses and the fact that both masses mainly move to the north.

THE DISTRIBUTION OF TEMPERATURE AND SALINITY

THE 1956 SURVEY

The section

The water mass A_2 is present in a width of 60 nautical miles (between Station No. 70 and 74) and has a thickness of about 250 m (Fig. 3). The water mass is brought into the area by the Norwegian Atlantic Current and makes a trough in the water mass A_3. On the coastal side A_3 is formed as a result of mixing between A_2 and Coast water, and on the offshore side by mixing between A_2 and water from the central part of the Norwegian Sea where the salinity is slightly less than in A_2. The main process, however, underlaying the formation of the mass A_3 in the bankarea, is the exchange of heat with the air. This results in a vertical mixing from the surface to the bottom and a decrease in temperature.

Coast water appears in a narrow zone near the shore. The isohalines slope steeply, indicating a strong northward current relative to the bordering mass.

At Station No. 77 an intermediate maximum in temperature appears with extreme values at 50 and 75 m depths. Originally, this water was of the type A_2, but receives admixture of Coast water in the upper part without significant heat loss to the air.

A ribbon of relatively cold water occurs in the Atlantic phase A_3 in the intermediate and deep layers at Station No. 78. This water has a slightly higher density than the surroundings and is probably formed on Haltenbanken, which partly is shallower than 150 m. Here, the vertical convection from surface to bottom occurs earlier in winter than in the deep waters surrounding the bank.

Another ribbon of relatively cold and less saline water in the Atlantic phase A_2 occurs outside the edge of the shelf. This minimum in the values of the parameters is partly due to an ascent of deep water and not caused by admixture of Coast water.

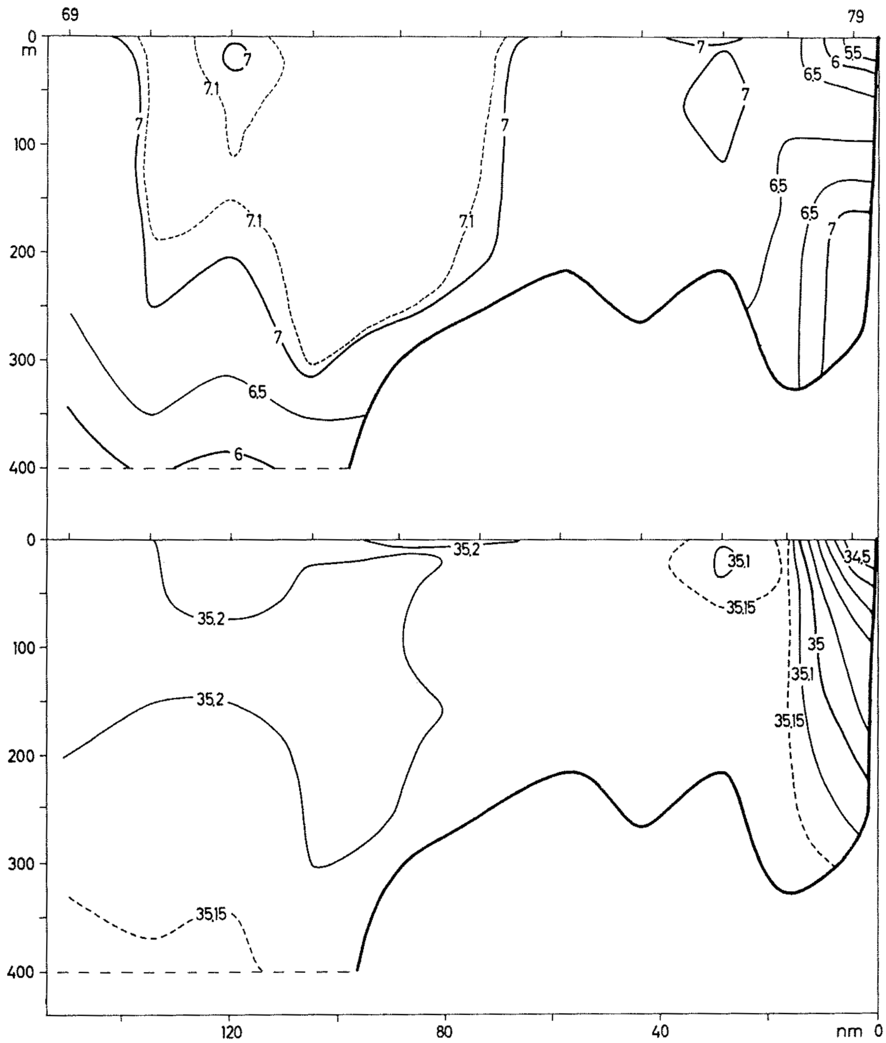

Fig. 3. Temperatures (°C) and salinities (‰) off Halten 20–21 February 1956.

The upper layer

The distribution of temperature at 4 m depth (Fig. 4), recorded continuously, permits more explicit studies than is possible by using the stations only. A change in the temperature in the upper layer is caused by mixing between Coast water and Atlantic water and by heat loss to the air only. The temperature, therefore, is a useful parameter for examination of the distribution of the main masses of the top layer, assuming that the heat exchange with the air is similar throughout the area investigated.

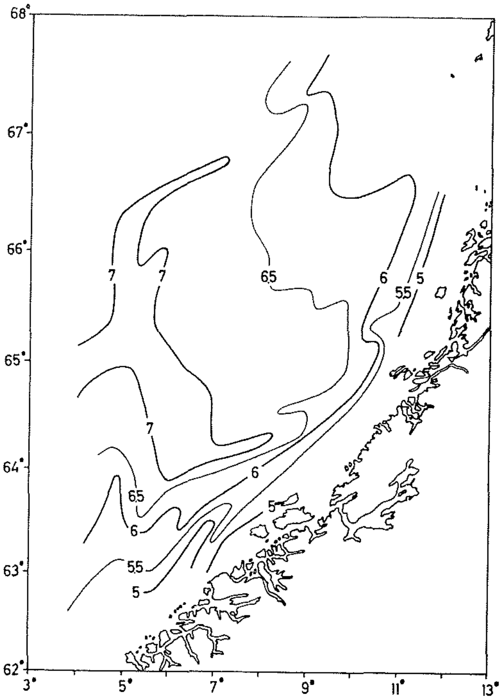

Fig. 4. Temperatures (°C) in the surface layer 18–24 February 1956.

It is evident that the Coast water splits into two branches outside Møre. The main branch runs parallel and close to the coast, whereas the other follows the edge of the continental shelf on top of the Atlantic water. The thickness of this branch was about 50 m in the southern part of the area, but was hardly traceable farther north in the section (Fig. 3).

The Atlantic water seems to move northward along the edge of the shelf, and one branch pushes towards the shore along the channel between Frøyabanken and Haltenbanken.

The intermediate layer

A general characteristic of the Atlantic waters A_1 and A_2 is that high temperature is associated with high salinity (Fig. 5). The distribution of these parameters show that the bulk of these masses moves northwards along the slope, and that two branches are pushed towards the coast in channels between the banks.

The minimum in salinity at Station No. 67 is due to admixture of waters from the outer branch of the coastal water.

The ribbon of ascended water in the phase A_2, mentioned before, gives rise to a minor minimum of temperature above and along the outer part of the slope.

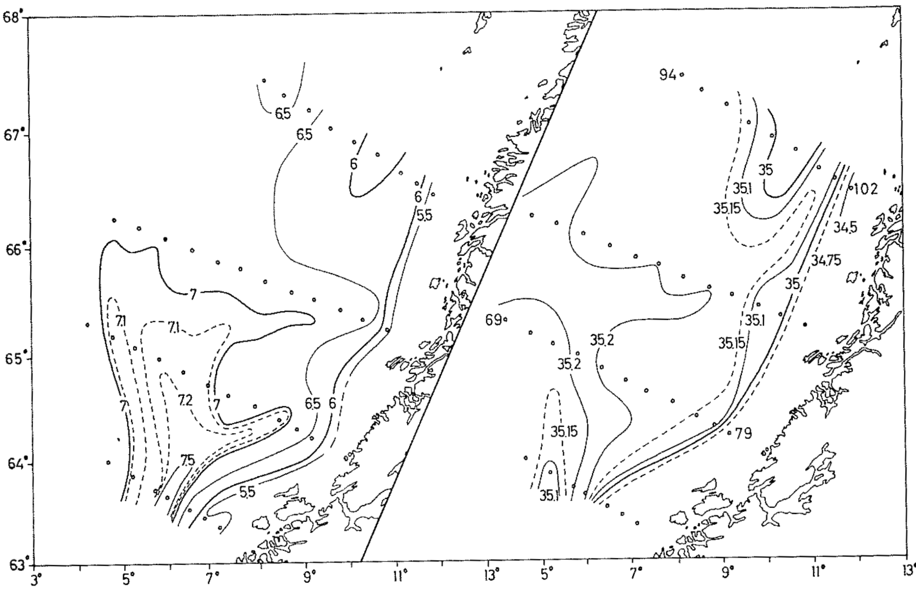

Fig. 5. Temperatures (°C) and salinities (‰) at 50 m 18–24 February 1956. Station grid is indicated.

THE 1968 SURVEY

Observations from 1968 give a more detailed account of the hydrographic conditions in the southernmost part of the investigated area. Fig. 6 shows that Coast water is found across the whole continental shelf as a wedge above the Atlantic water. The extreme values of the parameters in the Atlantic water occur at the inner end of the slope just below the Coast water. The transition layer between the two masses is thin, and

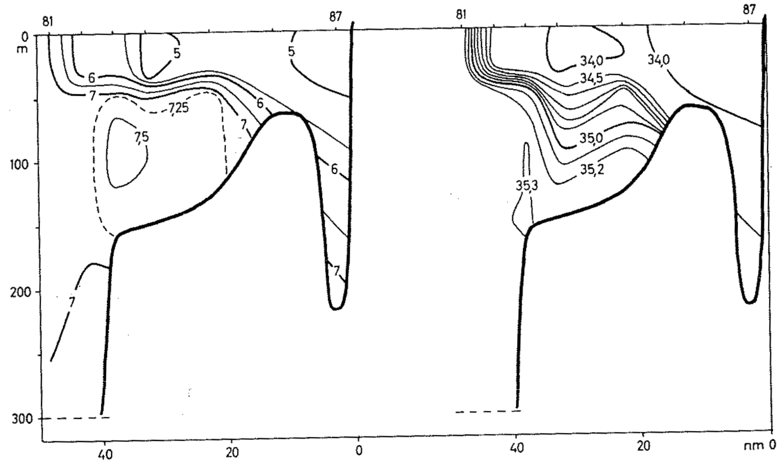

Fig. 6. Temperatures (°C) and salinities (‰) across Buagrunnen 10 March 1968.

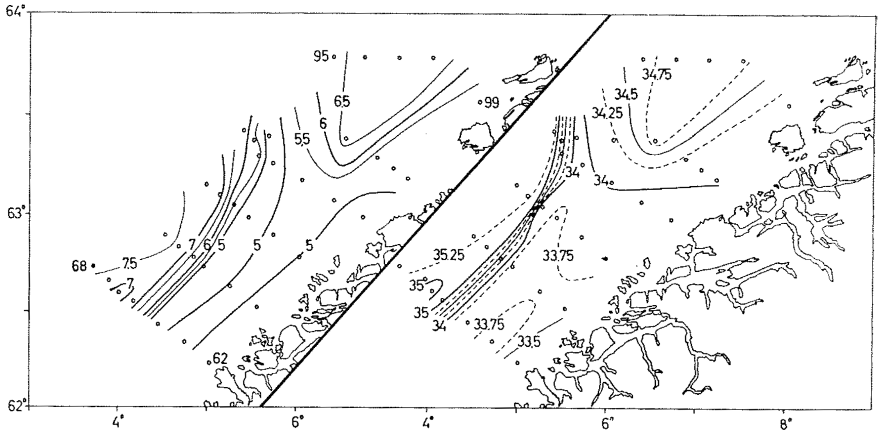

Fig. 7. Temperatures (°C) and salinities (‰) at the sea surface 7–12 March 1968. Station grid is indicated.

relatively large vertical and horizontal gradients occur both in temperature and salinity.

In the upper layer (Fig. 7), above the outer part of the shelf, there is a ribbon of water with low temperatures and salinities which seems to continue northwards along the slope. To the north of Buagrunnen temperature and salinity increase in northward direction.

The distribution of temperature and salinity at 50 m depth is illustrated in Fig. 8. There is a narrow zone of water with temperature maximum following the continental slope. This zone divides into two branches west of Grip. One part follows the continental slope northwards, the other bends to the east and follows the northern slope of Buagrunnen towards Grip.

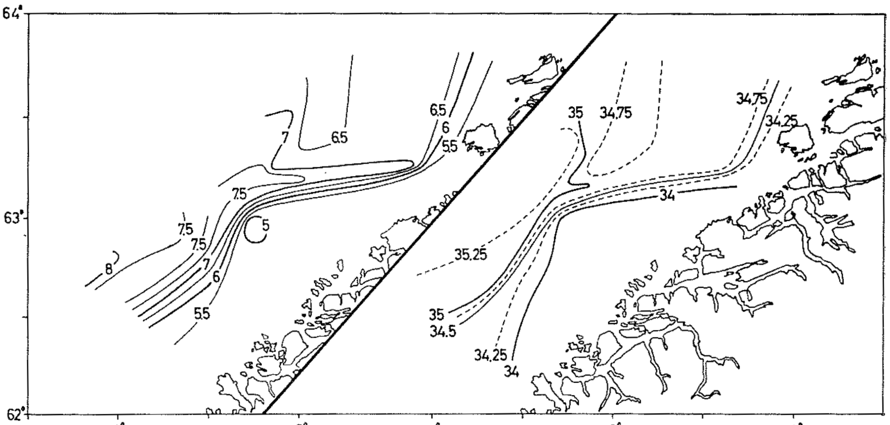

Fig. 8. Temperatures (°C) and salinities (‰) at 50 m 7–12 March 1968.

DISCUSSION AND CONCLUSIONS

From Fig. 2 it may appear as if the temperature and salinity of the Atlantic water were higher in 1968 than in 1956, and that the values of the corresponding parameters of the Coast water were lowest in 1968. This is mainly a geographical variation. The 1968 cruise covered the area where the two water masses recently had come into contact. Therefore, the largest vertical and horizontal gradients were found here. As reported earlier by HELLAND-HANSEN and NANSEN (1909), the gradients were smaller farther north due to mixing between these two water masses.

The seaward extension of the Coast water is as a rule larger in summer than in winter (HJORT and GRAN 1899). In the summer 1957 (LJØEN 1962), the 35.0‰ isohaline at the surface had an average distance of about 150 nautical miles from the shore. The corresponding distance in the winter 1956 was 10–40 nautical miles, except for an area just south of Lofoten. Besides the variation in time also large geographical variations appeared in the extension of Coast water. Off Møre the 35.0‰ isohaline intersected the surface at a distance of 40–50 nautical miles from the shore, while farther north, at Helgeland, this distance was only 5–10 nautical miles.

Off Møre the temperature and salinity of the Coast water were lowest at the outer part of the shelf (Fig. 7). This situation supports the suggestion of HELLAND-HANSEN and NANSEN (1909) that the northward velocity of the Coast water in this area is greatest at the edge of the shelf. On the main part of the banks the velocities are lower and may have various directions (DRAGESUND and NAKKEN 1968). The branch of Coast water which followed the slope northwards from the area west of Buagrunnen also seems to be present in summer (LJØEN 1962, Fig. 4B). The water of this branch mixed in all directions with water masses of higher temperature and salinity and therefore soon lost its original characteristics.

North of Buagrunnen the main bulk of Coast water probably flowed to the east and followed the coast northwards from Grip on. The strongest northward movement of the Atlantic water occurred outside the upper edge of the continental slope. However, there is evidence of a splitting of this current by longitudinal zones with discontinuity in the transversal distribution of the parameters. As in summer (LJØEN 1962), branches of Atlantic water pushed towards the coast in the channels between the banks. This pattern is obviously an effect of the bottom topography.

SUMMARY

1. The distribution of temperatures and salinities off the west coast of Norway have been studied, based on observations from cruises in February 1956 and March 1968.

2. The main flow of Coast water follows the edge of the shelf between Stad and Grip. West of Grip it divides into two branches. One follows the slope northwards, the other flows to the east and follows the coast northwards.

3. The Atlantic water follows mainly the slope, but branches of Atlantic water move to the east in the troughs between the banks.

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