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Geophysical Surveys of the Continental Shelf South of Nova Scotia*

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A number of geophysical exploration programs have been carried out on the Scotian shelf in recent years by the government, the universities, and the oil industry. These geophysical surveys have included sea bottom gravimetry (GOODACRE, 1964) and shipborne gravimetry (LONCAREVIC, 1965; KEEN and LONCAREVIC, 1966); sea magnetometer (BOWER, 1962); airborne magnetometer (HOOD, 1967); seismic profiler (MANCHESTER, 1965) and refraction seismic surveys (WILLMORE and TOLMIE, 1956; DRAKE et al, 1954; OFFICER and EWING, 1954; PRESS and BECKMANN, 1954; BARRETT et al, 1964; BERGER et al, 1965; KEEN and LONCAREVIC, 1966; EWING et al, 1966; EWING and HOBSON, 1966). In view of the considerable amount of geophysical data that has now been obtained, it is perhaps opportune to summarize the results to date in terms of the underlying geology of the continental shelf of Nova Scotia.

The accompanying figure (Figure 1) is therefore an interpreted geological map which has been deduced from these previous geophysical surveys. The generalized geology of the mainland is also shown, together with the bathymetry and depth determinations to the crystalline basement resulting from seismic and magnetic surveys. The former have been labelled S and the latter M in parentheses. The V's indicate the position of distinctive northeast-trending anomalies which are possibly due to igneous intrusives of Triassic age similar to the Triassic basaltic intrusives which occur on the south shore of the Bay of Fundy. MARLOWE (1964) has collected bottom samples containing basaltic fragments from The Gully which he feels may be of Triassic age.

In the western part of the Scotian Shelf, an area of Cretaceous sediments occurs to the north of Georges Bank (UCHUPI, 1966). Georges Bank itself is underlain by Tertiary and Cretaceous sedimentary strata which outcrop along the southern slope of the Bank (VERRIL, 1878; STEPHENSON, 1936; STETSON, 1936; EMERY and UCHUPI, 1965; and GIBSON, 1965). The seismic velocities of the crystalline basement beneath Georges Bank determined by OFFICER and EWING (1954) vary from 15,280 to 16,720 feet/sec (4.66 to 5.10 km/sec). It may be significant that the seismic velocities of the Quincy (Mississipian?) and Westerly granites which outcrop in New England average approximately 16,400 feet/sec (5.0 km/sec) (LEET and EWING, 1932). Thus there is a good possibility that the crystalline basement underlying Georges Bank may be granite. A gravity survey of the Bank would probably not be very illuminating because the density of the Quincy granite averages 2.66 gm/cc (JOYNER, 1963) which is very close to the average for crustal rocks.

In the northern part of the Scotian Shelf the Cambro-Ordovician Meguma Group of slates (Halifax Formation) and quartzitic greywackes (Goldenville Formation) produces a characteristic pattern of linear magnetic contours which parallel the coastline. The Halifax Formation has much more pronounced magnetic properties than the Goldenville Formation. The eastern and southern limit of the Cambro-Ordovician Meguma group and enclosed Devonian granites has been inferred from the magnetic pattern. Several large intrusions of granite occur beneath sediments south of Halifax and are readily observable on the aeromagnetic maps as featureless, magnetically low, oval-shaped areas. Farther to the south the amplitudes of the magnetic anomalies decrease and their wavelength increases because of the increased depth to the crystalline basement.

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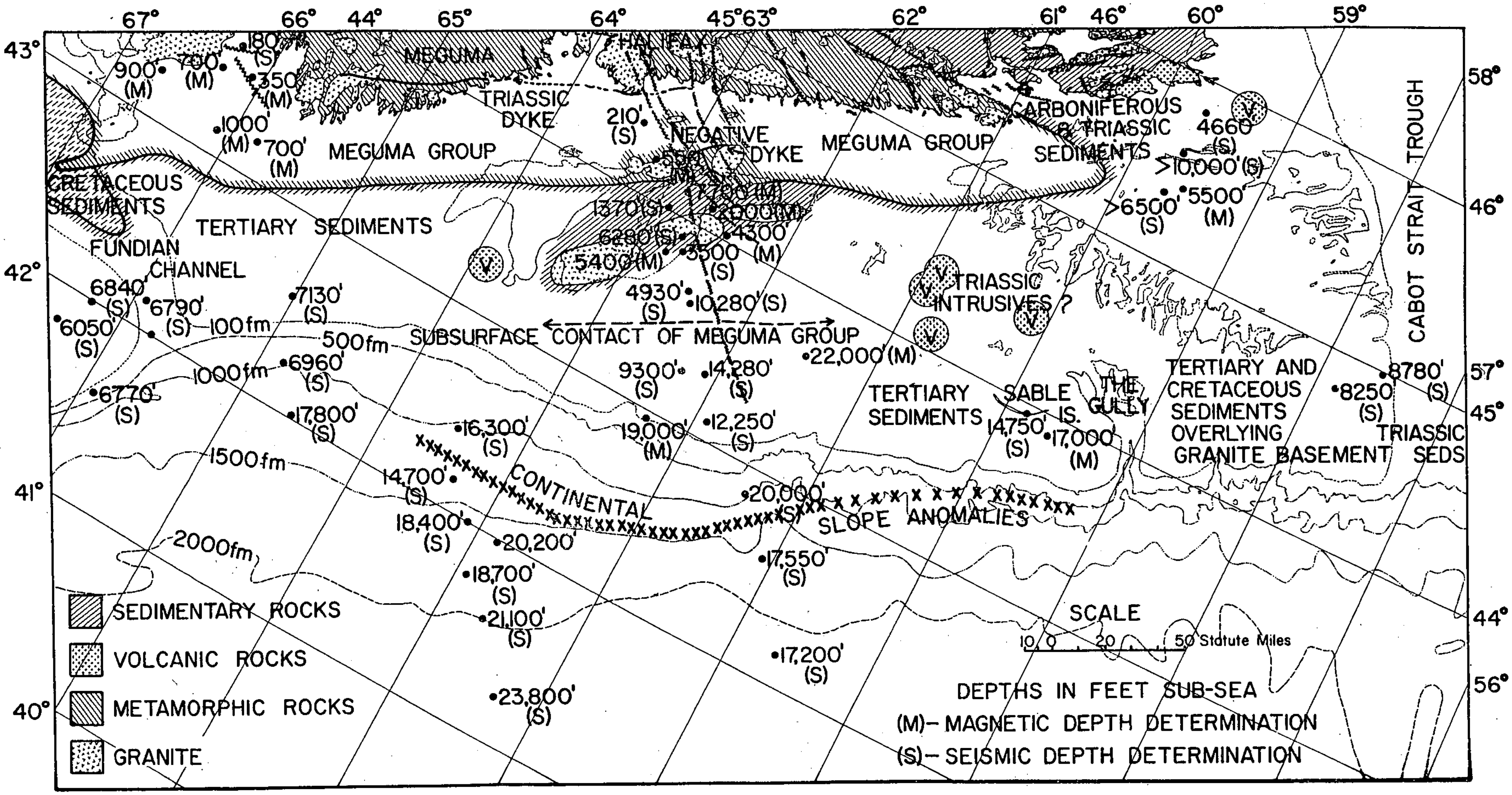

Figure 1 Interpreted geological map of the continental shelf of Nova Scotia.

A number of faults have been inferred from displacements in the aeromagnetic contours in the area south of Halifax. Most of the landward extensions of the faults appear on the G. S. C. maps of mainland Nova Scotia which resulted from the geological field work of E. R. Faribault during part of this century. One of these faults appears to pass along the North West Arm of Halifax Harbour.

The Meguma-Carboniferous contact at the ocean bottom has also been deduced from the aeromagnetic contours. The Meguma Group appears to continue underneath the Carboniferous sedimentary rocks and terminates in the southern part of the survey area. Depth determinations carried out for individual anomalies are in general agreement with those obtained by Lamont Geological Observatory during their 1950 seismic refraction survey (OFFICER and EWING, 1954). However, it is felt that the case for a basement ridge immediately north of the edge of the continental shelf has not been conclusively proven by Lamont Observatory's seismic results. Actually there is evidence from the magnetic survey of a ridge striking in a northeasterly direction, but depth determinations indicate that it is approximately 20,000 feet subsurface, which is twice the depth calculated by Lamont. Moreover, seismic surveys carried out by Dalhousie University in the Sable Island area indicate that any such ridge must lie to the south of the island (BERGER et al, 1965). It would thus be worthwhile to carry out additional geophysical surveys in the area to resolve the question.

The greatest thickness of sedimentary rocks on the Scotian Shelf seems to occur in the vicinity of Sable Island. The value of 14,750 feet was obtained by the seismic group at Dalhousie University (BERGER op. cit.).

A line of magnetic highs and lows is to be found immediately to the south of the hundred fathom contour on the edge of the continental shelf (indicated by the line of crosses on Figure 1), and these are presumably part of the well-known continental slope anomaly. The line of magnetic anomalies may form the first of the linear parallel anomalies which appears to be a common feature of deep ocean basins.

A zone of relatively flat magnetic gradient extends eastwards from Chedabucto Bay in an area where LONCAREVIC (1965) reported a negative gravity anomaly. MANCHESTER (1965) carried out seismic profiler surveys in the area and concluded that the Chedabucto Fault extends along the south side of Chedabucto Bay with a possible parallel fault along part of the northern side of the bay. The profiles also indicated that folded and faulted consolidated sedimentary rocks of probable Mississippian and Triassic age underlie Chedabucto Bay. EWING and HOBSON (1966) obtained three seismic profiles in the area and concluded that the resultant seismic data failed to delineate a basement configuration that would account for a large negative gravity anomaly. However, it is well-known that salt and gypsum occur fairly extensively throughout the Windsor Group of Mississippian age (WEEKS, 1957; BERSTICKER, 1963), and the negative gravity anomaly has been interpreted by LONCAREVIC and EWING (1966) as being due to a thick sequence of Mississippian evaporites with a density of 2.21 gm/cc. Certainly the graben-like structure would be conducive to the formation of the evaporites because of the provision of a partially enclosed trough in which the evaporites might be deposited. GARLAND (1965) has noted that gravity measurements in Africa and over the Rocky Mountain Trench indicate that negative anomalies associated with rift-like structures tend to occur as separated, closed minima and probably reflect the presence of low-density sediments in the troughs. In the Mandawa area of southern Tanzania a marked gravity low about 175 miles long and 50 miles wide appears to be due to the presence of massive halite (KENT, 1965). A deep drill hole encountered 7364 feet of salt.

In the eastern part of the Scotian shelf, Banquereau Bank appears to be underlain by Tertiary sediments (VERRILL, 1878; MARLOWE, 1965). Upper Cretaceous fossils have also been collected (DALL, 1925; STEPHENSON, 1936; MARLOWE, 1965) and it is probable that there is present a complete sequence of sedimentary formations ranging from Pleistocene to Cretaceous (and perhaps older), judging by the drilling results from the continental shelf off the United States (BUNCE et al, 1965). RVACHEV (1965) has described the surficial material collected during U.S.S.R. investigations on Banquereau Bank. The sea magnetometer results (BOWER, 1962) indicate that the crystalline basement underlying Banquereau Bank is composed of rock having a very low magnetic susceptibility. The basement rock has a seismic velocity of 15,100 feet per second (4.60 km/sec) (PRESS and BECKMANN, 1954). GARLAND (1953) in his gravity investigations in the Maritime Provinces found that the densities of the Devonian granites, which cover areas of many hundreds of square miles, range from 2.60 to 2.65 gm/cc. which is somewhat lower than the average for crustal rocks (2.76 gm/cc). By comparison the densities of slates and quartzites ranged from 2.70 to 2.75 gm/cc. with the slates (Halifax formation) having the higher density in general. It is well-known that seismic velocity increases with the bulk density of rocks (see for instance Figure 9-3 in Press, 1966) even though density appears in the denominator of the formula relating longitudinal velocity to the elastic constants and density. Thus it is to be expected that the seismic velocity of the Devonian granites of the Maritimes would be somewhat lower than that obtained for granites elsewhere. The author of this paper would conclude that the seismic velocity of the Nova Scotia Devonian granite usually lies between 15,000 and 16,000 feet per second (4.57 and 4.85 km per second), i.e. somewhat lower than that found in granites elsewhere. The Devonian granites also have negligible magnetic properties (HOOD, 1966) and this has been confirmed by the measurement of the susceptibility of a number of hand specimens kindly supplied by J.W. Gillis of the Geological Survey of Canada. It is concluded that the crystalline basement underlying Banquereau Bank is probably granite of Devonian age. Moreover, as a general rule the order of increasing susceptibility, density, and seismic velocity for the Meguma group and its enclosed granites would appear to be 1. Devonian granite, 2. Goldenville formation, 3. Halifax formation.

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