STUDIES BY THE REFLECTED-WAVE METHOD NEAR THE SOUTHERN KURIL ISLANDS IN 1968

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Abstract

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STUDIES BY THE REFLECTED-WAVE METHOD NEAR THE SOUTHERN KURIL ISLANDS IN 1968

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The geological structure of the Kuril island arc is of great interest from the standpoint of its connection with and conditioning by general processes in the development of the Earth' s crust. The southern part of the archipelago is of particular interest for study: two island chains, the presence of the most complete section of geological deposits ([1]), and comparatively detailed data on the deep structure of the Earth' s crust ([2,3]).

Fig. 1. Seismic time section of the reflected-wave method along profile VIII. The inset shows the location of the reflected-wave profiles. 1 —point of intersection with profile VII; 2 —shot-point number; 3-5 —reflecting boundaries: 3 —reliable position, 4 —uncertain construction, 5 —presumed position

In this area, in 1968, marine seismic investigations by the reflected-wave method (RWM) were carried out along profiles VII and VIII with a total length of about 320 km. The work was performed by the Pacific Expedition of the Institute of Marine Geology (VNIIMorgeo); interpretation of the seismic materials was carried out at SakhKNII. In their location, the RWM profiles partly coincide with DSS profiles 23 (1964) and 1-0 (1957): profile VII extends along the southeastern coast of Iturup Island, while profile VIII is directed from the island toward the ocean (inset to Fig. 1). The observation technique ([4]) provided for the possibility of continuous tracing of reflecting boundaries. In order to obtain more objective information in the absence of sufficient data on seismic-wave velocities, the RWM seismic sections were constructed in a time scale (along the vertical axis—the total arrival time of the waves). The part of the section along profile VIII shown in Fig. 1 is bounded on the ocean side by point 200, where the depth of the bottom is about 3 km, and the distance from Iturup Island is about 100 km.

The ocean floor in the near-Iturup part of the profile (observation points 1-160) is represented in the section by a flat reflecting boundary, gently inclined toward the ocean (predominant angle 10′) and lying at a depth of 300-500 m. A sharp deepening of the bottom (with an inclination of up to 10–15°) is observed only on the slope of the Kuril-Kamchatka deep-sea trench.

In the bottom relief along profile VIII, the structures of the Middle Kuril geosynclinal trough ([5]) and the Vityaz Ridge, which is the submarine continuation of the Lesser Island Chain ([6]), are not expressed; however, the main features of their deep structure are clearly reflected in the seismic-

section (Fig. 1): the area of the trough (the western part of the profile as far as observation points 60-80) is filled with thick sedimentary deposits; farther east lies an anticlinal structure, the crest of which is truncated by the ocean-floor surface, exposing its core in the interval between points 90-120. One limb of the anticline is buried beneath the sediments of the trough (points 50-80), while the other is exposed by the upper part of the slope of the deep-water trench.

More detailed RWM data are given below. In the northwestern part of the profile (points 1-50), a large number of reflected waves are recorded, following one another almost continuously in the interval from 0.4 to 2-3 sec and more. Distinct axes of in-phase correlation of a regular hyperbolic form, weak differentiation in dynamic properties, and a gradual decrease (on the whole) in intensity with time are characteristic of a monotonous layered section of sedimentary deposits. The thickness of individual beds in the seismic section is 50-100 m or more; however, taking into account the limits of the method' s capabilities and the interference of reflected waves, it may be assumed that the actual section of the geological deposits is characterized by finer layering.

The reflecting horizons distinguished within the sedimentary sequence form a synclinal trough, the axial part of which is located in the area of points 10-20. A small bend is also distinguished in the area of point 48. The maximum dip angles of the reflecting boundaries correspond to the lower part of the section on the Iturup limb of the trough and amount to 5-8°; in the middle part of the section the dip angles are 1-3°; higher up, there is further flattening of the boundaries and complete compensation of the trough by sediments. This latter circumstance is probably connected with a decrease in the rate of subsidence during the latest stages of development of the structure, and not with an increase in the rate of sediment accumulation, since as the trough was filled with sediments an ever larger amount of sedimentary material entering the basin was not deposited in it but was carried out into the ocean. If this supposition is correct, it may indicate an increased degree of consolidation of the basement of the Greater and Lesser Kuril island arcs.

In the sedimentary deposits along profile VII, oriented along the strike of the island arc, a consedimentary character of sagging is also observed (the axial part of the trough is located abeam Kasatka Bay), which is apparently connected with the uneven subsidence of individual sectors of the Central Kuril geosynclinal trough during the period of its formation.

The thickness of the sediments in the trough east of Iturup Island, detected by RWM, is 2.5–3.0 km, possibly more. The base of the sedimentary sequence is not detected by RWM. The velocity in the sediments does not exceed 2.0 km/sec.

DSS data along profile 1-0 (?) indicate that the thickness of the sediments in this area is about 4 km for an adopted velocity in the sediments of 2.8 km/sec. In more detailed studies on profile 23 ([3]), the velocity was determined to be 2.2–2.6 km/sec, and the maximum thickness 3.5 km.

Farther along profile VIII (points 50–90), in the eastern direction, the wave pattern gradually changes: the duration of recording of the reflected waves described above decreases, and at later times a second group of waves appears, distinguished by less stable tracking, larger time intervals (0.2–0.5 sec), and dipping axes of in-phase correlation.

The horizons to which the reflected waves of the second group correspond lie unconformably beneath the gently dipping sedimentary beds of the trough and dip toward Iturup. With the assumptions about velocity parameters that will be set forth below, the dip angles of the various reflecting surfaces vary within 10–25°. The maximum thickness of the sequence reaches 2.5–3.0 km.

Gradually along the profile there is also a decrease in the duration of recording of the waves of the second group, and in the segment of points 90–120 only waves reflected from the bottom are distinguished on the seismograms, in some cases—from nearby boundaries, and their multiple waves, formed at the water-air boundary, the number of which reaches 6 and more, indicating the high acoustic rigidity of the rocks.

In the segment of the profile between points 120–200 the duration of the seismic record increases, reaching at point 180 a maximum value of 1 sec. (counting from the bottom reflection for single-reflection waves). The multiplicity is reduced to 2–3. Apparently, the density of the rocks here has an intermediate value between the rigid and loose formations noted above. The thickness of the deposits varies approximately from 0 to 1–2 km; the boundaries dip toward the ocean.

DSS data indicate that in the area of the Vityaz Ridge the refracting boundary with a velocity of 5.0 km/sec, forming an uplift, reaches the sea-floor surface or lies close to it ([2]). On profile 22 (in the area of intersection with profile VIII), rocks with a velocity of 4.6 km/sec have a thickness of 3–5 km, are underlain by a layer with a velocity of 6.0–6.2 km/sec, and are overlain by sediments up to

1 km thick, in which the velocity is 2.0 km/sec. However, farther north on this same profile, beneath the sea-floor surface there occur rocks characterized by a velocity of 3.4-3.6 km/sec and a thickness of 2 to 5 km; the boundary velocity in the underlying rocks is 5.1-5.6 km/sec ([3]).

Comparing the RWM and DSS data, it may be assumed that the core of the anticlinal structure corresponding to the Vityaz Ridge is composed of dense rocks with a velocity of 5.0-5.6 km/sec, which cause intense reflection of seismic energy from their surface and probably represent a granite-metamorphic complex. The deposits on the flanks of the structure are characterized by a velocity of 3.4-3.6 km/sec and probably correspond to Upper Cretaceous-Paleogene (?) rocks exposed on the islands of the Lesser Kuril Ridge and represented mainly by tuffaceous and volcanogenic material, with insignificant development of normal sedimentary rocks (([6]) et al.). The velocity in Cretaceous rocks on Sakhalin is also determined as 3.3-4.0 km/sec ([7], [8]).

As for the layer with a velocity of 4.6 km/sec, detected on DSS profile 22, it remains unclear whether it represents one of the named rock complexes or both, the boundary between which could not be detected in the seismic investigations.

The supposition of a Cretaceous-Paleogene (?) age for the rocks composing the flanks of the anticlinal uplift on the RWM profile is also confirmed by the character of their relationship with the deposits of the Central Kuril trough. The age of the latter, by comparison with rocks developed on the adjacent islands of the Greater Kuril Ridge, may be estimated as Neogene-Quaternary. The deposits of the Kuibyshev and Rybakov suites of the Middle and Upper Miocene within the southern group of islands of the Greater Ridge are characterized by a predominance of normal sedimentary deposits, the greatest thicknesses in the section, and continuity of sedimentation, which also extends into later, Pliocene time ([9]). These same features, according to RWM data, are also inherent in the sedimentary deposits of the Central Kuril trough, which permits the synchronism of their accumulation to be assumed.

In the section of the normal sedimentary deposits of Iturup Island, sandstones, argillites, and siltstones predominate. The rocks of the Central Kuril trough, judging from the low velocity values, are probably represented by looser sandy-clayey material. Apparently, the rocks developed on the island were compacted during the subsequent period of geoanticlinal development of the Greater Kuril Ridge. This also explains the steeper occurrence ([10]) of the deposits of the Kuibyshev and Rybakov suites.

Rocks of the core of the anticline exposed on the bottom surface (or covered by sediments of insignificant thickness) attest to denudation that took place in the past and, apparently, to a recent subsidence of the structure below sea level.

The subsidence can probably be dated to the beginning of Late Quaternary time —the epoch of significant submergences of this region (^1).

Modern submergences are clearly expressed in the relief of the ocean floor in the eastern part of the anticlinal structure and on the slope of the trench. Thus, in the area of point 117 a step with an amplitude of about 60 m is observed; on the slope of the trench there are moat-like depressions (points 240–280 and 345–365), partly filled with sediments and, apparently, connected with the uneven or block-like character of tectonic movements. Manifestations of modern tectonic movements are also noted on the outer slope of the trench (^11). The character of the sedimentary section on the oceanic wing of the Vityaz Ridge (an increase in the thickness of deposits toward the ocean and in the angles of dip of boundaries with depth), as well as the truncation of sedimentary beds by the steep slope of the trench, probably indicate the later emergence and development of the structure of the Kuril–Kamchatka Trench in comparison with the geological deposits of the Lesser Kuril Ridge.

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Note: Figure translations are in progress. See original paper for figures.