Doklady Earth Sciences, Vol. 361, No. 5, 1998, pp. 632–634.
Translated from Doklady Akademii Nauk, Vol. 360, No. 5, 1998, pp. 666–668.

Collision of the Olyutor Island Arc with the Eurasian Continental Margin: Kinematic and Age Aspects

A. V. Solov'ev,* M. T. Brandon, J. I. Garver,*****
Corresponding Member of the RAS N. A. Bogdanov,* M. N. Shapiro,** and G. V. Ledneva**

Received January 27, 1998

Fragments of the Olyutor island arc formed in the Pacific during the Late Cretaceous–Paleogene [1, 8]. At the time they were located far away (about 2000 km) from the Eurasian continental margin [2, 3]; at present, this is a part of the Olyutor–Kamchatka fold region. In the modern structure, Cretaceous marginal-sea and island-arc rock complexes are thrusted along the Vatyna–Vyvenka–Lesnaya suture zone upon Cretaceous–Paleogene terrigenous deposits of the Ukelayat trough and Western Kamchatka, which were formed along the continental slope of Eurasia [1, 5, 8–10] (Figure). This work is devoted to the kinematics of the Vatyna–Vyvenka–Lesnaya suture and the timing of collision of the Olyutor island arc with the continental margin.

Kinematics of the Vatyna–Vyvenka–Lesnaya suture zone. Investigation of suture zone kinematics is based on studies of mesostructural kinematic indicators such as asymmetric folds, Riedel composite structures, and thrust cutoffs [4, 11]. Structural observations were carried out in the Vatyna–Vyvenka suture in the Olyutor zone, namely the Il'Pi and Matysken river district (area I) and the Tapel'vayam River basin (area II) [5], and in the Lesnaya suture (area III) (Fig. 1). Kinematic indicators show that allochthonous nappes composed of marginal-sea and Olyutor arc-related deposits were thrusted in the northeastern direction. The reconstructed direction displays similar orientation in all the areas situated at a significant distance from each other. A different direction of the tectonic movement was registered for the Tapel'vayam River district on the western slope of the Gal'moenan massif) (area II); however, the reliability of this estimate is very low, because it is characterized by a high confidence angle (±88°).

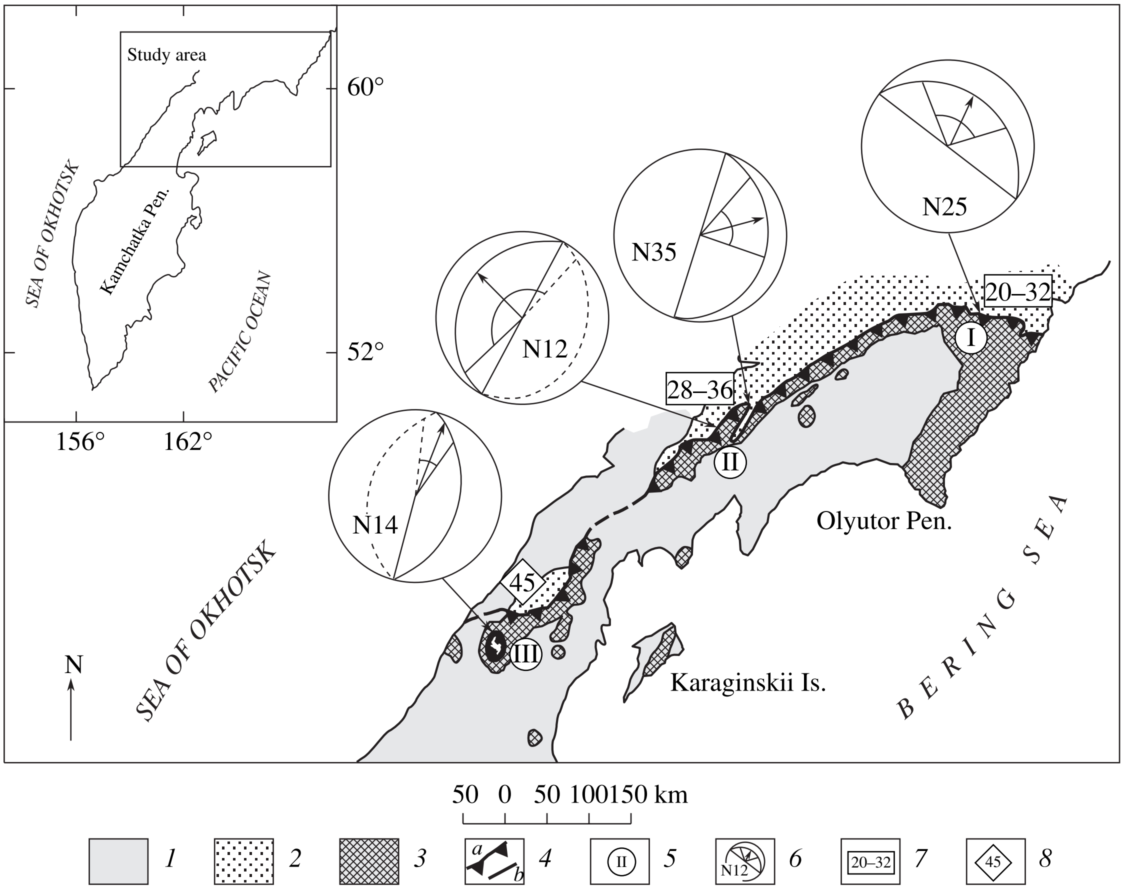
Thus, in the northern part of the Olyutor zone (area I), the direction of tectonic movement was orthogonal to the Vatyna–Vyvenka suture front (Fig. 1). On the other hand, the direction of the allochthonous mass movement in the southern part of the Olyutor zone (area II) and Kamchatka isthmus (area III) was oriented at an acute angle relative to the suture boundary, which allows the Vatyna–Vyvenka–Lesnaya suture in the region in question to be considered as representing a transpressive structure with a significant sinistral strike-slip component.

Timing of the collisional process. Previous researchers estimated the timing of the collision of the Olyutor–Kamchatka island-arc system with the Eurasian margin based on geological data (the age of neoautochthon, collisional intrusions, etc.). In the course of our studies, we attempted to reconstruct a chronology of collisional events using the method of fission-track dating of apatite and zircon and considering the obtained results in combination with geological data.

Unreset detrital zircon (resetting at a closure temperature [7] of about 180–260°C) provides information on the provenance and, thus, on the age of parental rocks. The age of the youngest population of detrital zircon grains constrains the upper age limit of host rock deposition. The youngest grains of unreset detrital zircon from six sandstone samples from the Ukelayat trough are dated at 43.8 ± 3.6 and 66.1 ± 6.3 Ma [12]. These ages indicate that the formation of terrigenous deposits, including the continuation of the Ukelayat trough during this time period and, thus, constrain the lower age limit of the collision in the Olyutor zone.

The age of reset detrital apatite (resetting at a closure temperature of about 80–110°C [7]) corresponds to the period of cooling of the parental terrigenous rocks. In the case considered, heating may be related to the formation of postcollisional orogen, whereas cooling is related to the denudation of the latter. The reset apatite age of 35 samples of Ukelayat sandstone in the

* *Institute of the Lithosphere, Russian Academy of Sciences, Staromonetnyi per. 22, Moscow, 109180 Russia*
** *Department of Geology and Geophysics, Yale University, Whitney Avenue 210, New Haven, P.O. Box 208109 USA*
*** *Geology Department, Union College, Schenectady, NY, 12308-2311 USA*
**** *Joint Institute of Physics of the Earth, Bol'shaya Gruzinskaya ul. 10, Moscow, 123810 Russia*



Distribution of the Cretaceous rock complexes of the Olyutor and Ukelayat zones and data on the kinematics of the Vatyna–Vyvenka–Lesnaya suture zone. (*1*) Cenozoic; (*2, 3*) Upper Cretaceous formations: (*2*) terrigenous rocks of the Ukelayat trough and Western Kamchatka, (*3*) volcanogenic–siliceous–terrigenous rocks of the marginal sea and Olyutor island arc; (*4*) the Vatyna–Vyvenka–Lesnaya suture: (*a*) proven, (*b*) assumed; (*5*) Vatyna–Vyvenka thrust areas: (I) Il'pi and Matysken rivers, (II) Tapel'vayam River, (III) southern flank of the Lesnaya uplift (Lesnaya thrust); (*6*) diagrams displaying the direction of movements of the hanging wall (allochthon) relative to the foot wall (autochthon) in the Vatyna–Vyvenka–Lesnaya suture zone based on the analysis of inner axes of rotation [4, 11]; the Wulff net; projections on the upper and lower hemispheres are shown by solid and dashed lines, respectively; the arc of the larger circle corresponds to the orientation of the "median" thrust surface in the given area; the arrow designates a synoptic vector of the hanging wall displacement reflecting the median regional direction of tectonic displacement in the thrust zone; the arc indicates the confidence angle; (N) is the number of structural elements (Riedel composite structures, asymmetric folds, thrust cutoffs) used in calculations; (*7*) fission-track dates (Ma) of reset detrital apatite from the Ukelayat trough sandstone; age is interpreted as the period of rock cooling in the course of postcollisional orogen denudation; (8) the age of collision estimated using geological data [9, 10].

northern Olyutor zone (area I) indicates that the rock sequence cooled about 20–32 Ma ago. On the other hand, the apatite age of Ukelayat sandstone from the Olyutor zone (area II) depicts a cooling event at about 28–36 Ma ago [12] (Figure). These dates constrain the upper age limit of collision of the Olyutor island arc with the Eurasian margin.

Conclusion. Assuming that the direction of the allochthonous block movement based on mesostructures in the Vatyna–Vyvenka–Lesnaya suture reflects the direction of the arc movement at the collisional stage, we can conclude that the Olyutor arc fragments most likely drifted in a northeastern direction. Such displacement can be related to tangential stress at the convergent boundary of the Pacific plate in the course of its oblique subduction, which continued up to 42 Ma ago. Fragments of the Olyutor island arc could move in a northeastern direction along regional strike-slip faults oriented subparallel to the Kamchatka paleomargin. The existence of such strike-slip faults was assumed by Utkin [6] and Geist *et al.*[13]. The boundary-normal velocity component of the Pacific plate was responsible for the formation of marginal thrusts at the boundary of Eurasia with the Olyutor island arc.

The analysis of published data and the obtained fission-track dates allow us to suggest that the collisional process occurred simultaneously along the entire Eurasian margin. In the Kamchatka isthmus area, collision terminated not later than the mid-Eocene because the Lesnaya thrust was already formed at that time, which is evidenced from the fact that it is overlain by the mid-Eocene effusive rocks of the Kinkil Formation and intruded by comagmatic granites [9, 10]. In the Olyutor zone, the general deformation of the allochthonous complex rocks is considered to have occurred substantially later, i.e., in the mid-Miocene time [8]. Such an age estimate is based on the occurrence of continuous Paleogene and Miocene (lower half) sections in the Il'pi Peninsula (the southern Olyutor zone). On the other hand, the accumulation of the Ukelayat trough deposits terminated before the mid-Eocene (based on zircon fission-track dating). The exposure of these deposits to postcollisional denudation after heating, as suggested by apatite fission-track dating, which could be related to collisional processes, occurred no later than the late Eocene–Oligocene (36–28 Ma) in the southern Olyutor zone and the terminal Oligocene–earliest Miocene (32–20 Ma) in its northern sector.

The age of collision of the Olyutor island arc with the Eurasian margin became successively younger in the south–north direction, and the flysch trough separating the arc from the continent was closed in a zipper-like mode. This process was, however, irregular. The southern segment of the arc ultimately joined the continent as early as at the beginning of the Eocene. Simultaneously, the northern segment ceased its fast drift toward Eurasia but remained to be separated from the latter by the remnant Ukelayat trough. The further evolution of the continental margin can be divided into the following stages: deformation of the Ukelayat trough in the mid-Eocene–early Miocene and drift of the Olyutor arc fragments to the nearly current position in the mid-Miocene time.

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation, United States (grant nos. EAR 94-18989 and EAR 94-18990) and the Russian Foundation for Basic Research (project nos. 96-05-79054, 97-05-79025, and 98-05-64525).

REFERENCES

1. Bogdanov, N.A., Vishnevskaya, V.S., Kepezhinskas, P.K., *et al., Geologiya yuga Koryakskogo nagor'ya* (The Geology of the Southern Koryak Highlands), Moscow: Nauka, 1987.
2. Kovalenko, D.V., *Geotektonika,* 1996, no. 3, pp. 82–96.
3. Pecherskii, D.M. and Shapiro, M.N., *Fiz. Zemli,* 1996, no. 2, pp. 31–55.
4. Solov'ev, A.V., in *Geologicheskie issledovaniya litosfery* (Geological Studies of the Lithosphere), Moscow, 1996, pp. 57–61.
5. Solov'ev, A.V., *Cand. Sci. (Geol.–Min.) Dissertation*, Moscow: Inst. Lithosphere, RAS, 1997.
6. Utkin, V.P., *Sdvigovye dislokatsii i metodika ikh izucheniya* (Strike-Slip Dislocations and the Methods of Their Study), Moscow: Nauka, 1980.
7. Faure, G., *Principles of Isotope Geology*, New-York: Wiley, 1986. Translated under the title *Osnovy izotopnoi geologii*, Moscow: Mir, 1989.
8. Chekhovich, V.D., *Tektonika i geodinamika skladchatogo obramleniya malykh okeanicheskikh basseinov* (The Tectonics and Geodynamics of the Folded Framing of Small Oceanic Basins), Moscow: Nauka, 1993.
9. Shantser, A.E., Shapiro, M.N., Koloskov, A.V., *et al., Tikhookean. Geol.*, 1985, no. 4, pp. 66–74.
10. Shapiro, M.N., *Geotektonika,* 1995, no. 1, pp. 58–70.
11. Cowan, D.S. and Brandon, M.T., *Am. J. Sci,* 1994, vol. 294, pp. 257–306.
12. Garver, J.I., Bullen, M.E., Brandon, M.T., Solov'ev, A.V., Ledneva, G.V., and Bogdanov, N.A., The Age and Thermal History of the Ukelayat Flysch and Its Bearing on the Timing of Collision of the Olutorsky Terrane, Northern Kamchatka, Russian Far East, *VII Int. Zonenshain Conf.,* Moscow, 1998.
13. Geist, E.I., Vallier, T.L., and Scholl, D.W., *Bull. Geol. Soc. Am.*, 1994, vol. 106, no. 9, pp. 1182–1194.