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Karelia's pristine carbon-containing rocks are wonderful natural formations of the Proterozoic age—about two billion years old and having no analogs in the geological history of the earth. Such rocks have a wide range of carboniferous inclusions, rich and lean alike. Shining schungites certainly take pride of place among the minerals of that northern land. These objects command close attention of the home research institution—the Karelian Research Center of the Russian Academy of Sciences.

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PLUTONIC GEODYNAMICS AS THE MECHANISM OF EARTH EVOLUTION

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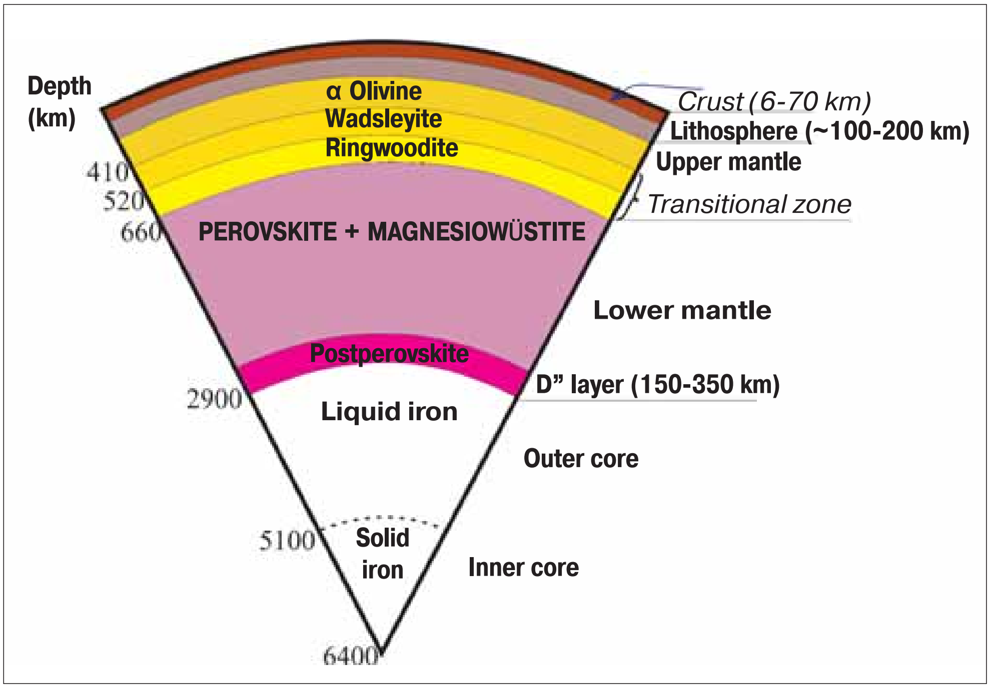
The last fifty years have seen great changes in geological knowledge. Owing to achievements of seismic tomography, two vast regions of hot matter have been detected in the bowels of the earth reaching as far down as the central core. Remarkably, their projections to the planet's surface actually concur with hot fields of the mantle identified by Soviet geologists thirty years ago by indirect evidence. These and related discoveries underlie the global geodynamics theory that has made it possible to link plutonic processes within the mantle to global surface geology.



Internal structure of the earth. Upper/lower mantle interface, 660 km. Partly molten matter contained in the upper mantle often contacts the asthenosphere.

INTERNAL STRUCTURE OF THE EARTH

First, some background information. In his major work on fundamentals of geology (published in 1830-1833 in three volumes) the British geologist Charles Lyell formulated the principles of what he termed *actualism* (contemporary observations make it possible to postulate geological processes of the past) and *uniformism* (all natural changes notwithstanding, the laws responsible for them remain immutable). Later on two American geologists, James Hall and James Dana (in 1858 elected honorary member of the St. Petersburg Academy of Sciences) came up with the concept of geosynclines (with respect to mobile zones of the earth) explaining the origins of folded mountain masses. And the Russian earth scientist Acad. Alexander Karpinsky identified stable regions on earth, the platforms (1887, 1894). The works of these eminent scientists became a groundwork for the geological paradigm of the late eighteen-hundreds and the nineteen-hundreds up to the 1960s when the plate tectonics theory came to the fore.

Our planet is composed of a number of spheres (shells) that vary in thickness and that are different in their mineral and chemical composition. Their seismic boundaries are clear-cut. The uppermost shell, the lithosphere (up to 10 km thick in the oceans and to 200 km and more on the continents). It is superposed by the earth crust, 6 to 70 km thick. The lithosphere is rather brittle—this is where earthquakes take place causing splitoffs and rents giving vent to the hot matter of the mantle* capable of reaching out to the global surface.

Lying underneath the lithosphere is the asthenosphere; it extends from the base of the lithosphere down to about 700 km; this is a comparatively weak layer that readily deforms by creep. The asthenosphere contains partly molten matter responsible for convective (heat-transferring) flows. In mid-ocean ridges (MOR) the asthenosphere comes up to the earth surface; it causes a fusion of MOR basalts with the low content of lithophilic elements.** The asthenosphere "lost" most of them 1.8 to 2 bln years ago to the earth's crust being formed then. The lower mantle was not implicated in these events since its composition is more akin to the primary mantle of the earth. We should note here that nearly half of the global mass is composed of Mg-perovskite, stable in a wide range of pressure. This is the basic mineral of the lower mantle.

The D" layer discovered in the 1980s is of major significance for processes of plutonic geodynamics. It lies on the foot of the mantle. As much as 150 to 350 km thick, it is noted for a high temperature gradient: about 4,000 °C on the bottom and 3,000 °C toward the upper boundary. It is through this layer that the mantle is interacting with the core.

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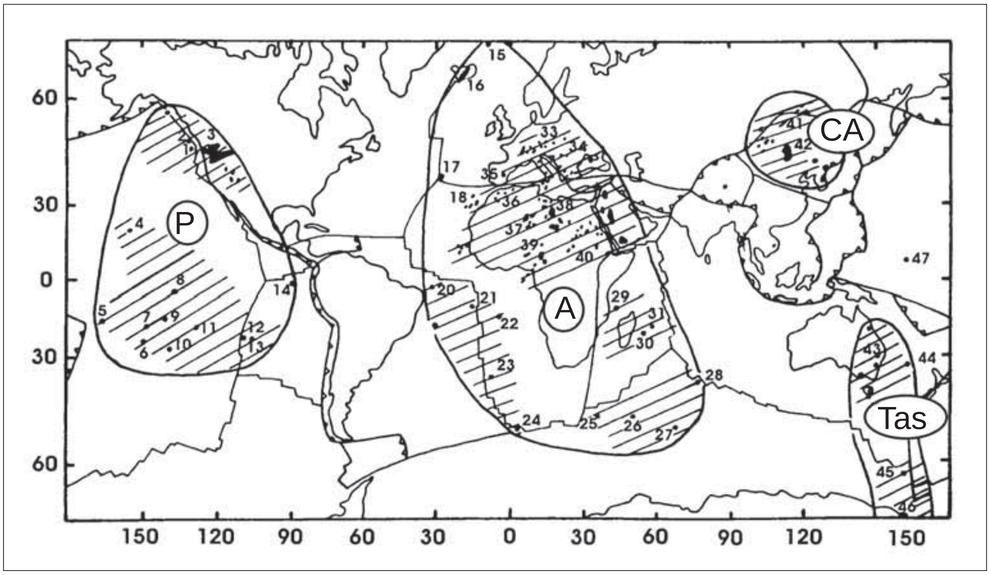
* The layer of the earth's interior between the crust and the core reaching down 2,900 km ; we distinguish between the upper (down to 660 km) and the lower mantle extending to the core.—*Ed.*

** A group of chemical elements (as many as 53) making up the bulk of minerals in the crust.—*Ed.*



By surface manifestations of intraplate magmatism over the last 15 mln years as many as 47 hot spots have been identified. They group into four extensive (up to 10 thous. km across) but compact zones called "hot fields of the earth mantle"; African, Pacific, Central Asian and Tasmanian (Sonenschein, Kuzmin, 1983).

The discovery of postperovskite in 2002 to 2004 was a great achievement of experimental mineralogy. It has the same chemical composition as perovskite, though its density is 1.2 percent higher. As shown by experimental data, the present temperatures in the earth's interior are conducive to this mineral's formation to a depth of 2,600-2,900 km, i.e. within the D" layer. Our estimates of the thermal evolution of the globe's interior invite the conclusion that postperovskite started forming after a considerable cooling of the earth around 2.3 bln years ago. From that time on the continents began to grow faster (nearly twice as fast), that is plate tectonics confined to the upper mantle happened to be at work.

PLATE TECTONICS THEORY

Looking into a bathymetric map of the ocean floor in 1961, Robert Dietz, a British geophysicist, and Harry Hess, a U.S. earth scientist, came to the conclusion that extended mountain ridges towering above abyssal (deep-water) valleys to 1-2 km are confined to the central parts of the oceans. They demonstrated that a new crust was being formed within the rifted structures of these ridges. The two scientists called the process of sea floor extension "sea floor spreading".

In 1963 two British geophysicists, F.S. Vine and D.H. Matthews, confirmed the phenomenon of spreading through the presence of banded (striped) magnetic anomalies formed via magnetization of oceanic core rocks in line with the polarity of the global magnetic field changing periodically from direct (present situation) to reverse.

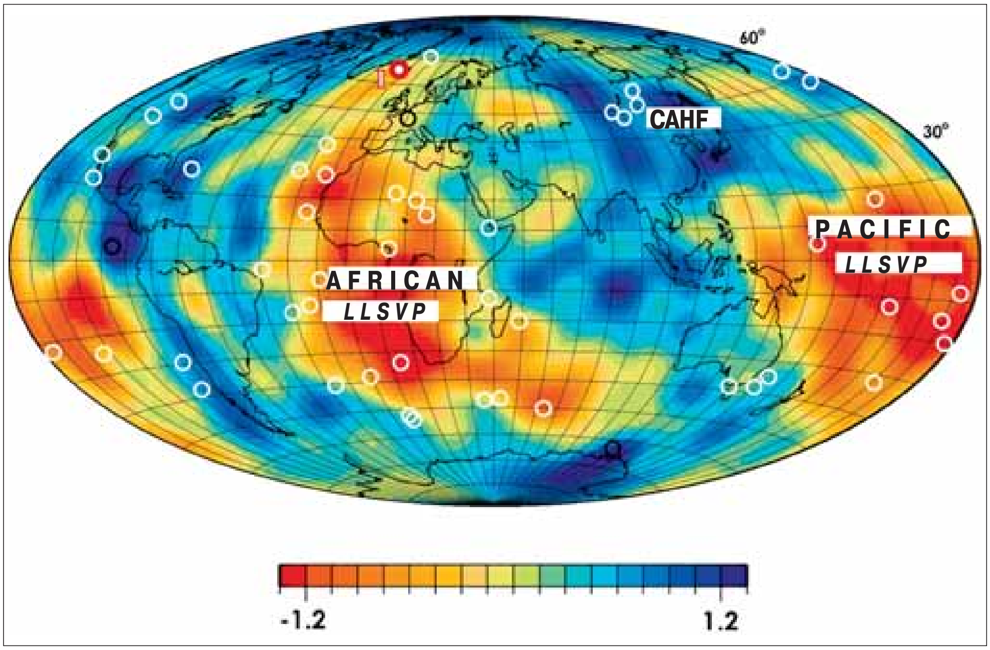
Then, in 1965, John Wilson of Canada singled out a special type of fractures—transformation faults—appearing in horizontal shifts of the oceanic lithosphere sidewise from the mid-ocean ridges. Thereupon, in 1968, Jayson Morgan of the United States and other research scientists pointed to essential differences between the abysmal geophysical structures of the ridges and the zones of festoon islands (island arcs). The latter are characterized by underthrusts, or the sinking of the oceanic lithosphere into the mantle to a depth of 600 km. This is the process of subduction ("pushing under").

As soon as plate tectonics fundamentals had been devised in full, the plate tectonics theory explaining the present-day global dynamics gained worldwide recognition. Its principles are rather easy to grasp.

The lithosphere and the asthenosphere, the two outer envelopes of our planet, are interactive. The asthenosphere's matter is capable of flowing and, consequently, of causing convective flows sustained by the energy of the inner envelopes. The lithosphere, a hard rocky shell encasing the earth, reacts but passively to processes in the asthenosphere. It is dissected by two narrow belts or zones noted for high tectonic (seismic in particular) and magmatic activity: these are the rifted mid-ocean ridges and subduction zones. Such zones as well as the transformation faults break the lithosphere into hard solid plates that, acted upon by viscid friction forces brought about by convective (or other) flows in the asthenosphere, are in motion with respect to one another.

HOT SPOTS

As far back as 1963, when the plate tectonics theory was still in its swaddling clothes, John Wilson called attention to active volcanoes within oceanic plates; such volcanoes formed chains oriented opposite the vector of plate move-



The "hot fields" boundaries concur roughly with LLSVP contours (LLSVP, large low shear velocity provinces known also as superplumes). LLSVP relation to the present manifestations of volcanicity is confirmed by the localization of 49 hot spots known to date on the terrestrial surface; the mantle provinces determined by the method of seismotomography (Sonenschein, 1991; Burke, Torsvik, 2004).

ments. These chains, he proposed, were linked to hot spots of the mantle burning through the lithosphere above.

Many researchers accepted the hypothesis of hot spots of the mantle. It was suggested (and then confirmed) that such hot spots are actually geochemical anomalies, for their magmatic rocks are enriched (if compared with MOR) with many rare lithophilic elements, and this is not typical of upper mantle melts. Such rocks are connected with spots of the heated asthenosphere which, while immobile, are sustained by mantle plumes or streams coming up from lower mantle depths, possibly, from the core/mantle interface. In oceans the intraplate magmatism is represented mostly by basalts of plateaux and islands set off into a peculiar geochemical type, OIB (ocean island basalt). Similar in composition are basalts of trap* provinces, in Siberia for one.

The notions of hot spots made for the presence of narrow (about 50 km across) mantle jets (columns) piercing all through the mantle but remaining immobile (compared with lithospheric plates for tens of millions of years). A volcano is formed within a plate like that traveling above a "spot" of heated mantle; when the plate moves with respect to the hot spot yet another volcano is born; as a result today we see a chain of dead volcanoes actually tracing the trail burned through by the hot spot. Conspicuous in this regard is the Hawaiian hot spot implicated in the appearance of the Hawaiian Emperor Ridge in the Pacific that has been in existence for nearly 100 mln years.

Some earth scientists, however (like Keit Runcorn for instance), maintained that the geological and physicochemical parameters of the mantle make it but little probable that such columns could ever be, and they propounded different hypotheses to explain the origins of hot spots. But all these hypotheses did not allow for the presence of any plutonic mantle structures capable of acting on geological processes in the upper shells of the earth.

HOT FIELDS OF THE MANTLE

By 1980 intraplate magmatic activity had been proved both for the oceans (volcanic islands and plateaux) and for the continents alike. Yet there were no works on how hot spots (as plutonic formations) and surface geological structures were interconnected. To make up for this gap Leo Sonenschein (1929-1993), an eminent Soviet earth scientist and full member of the Russian Academy of Sciences, suggested that one of the authors of the present article, Mikhail Kuzmin, address this problem. The approach was quite simple—find purely geographical distribution patterns for intraplate magmatism products on the terrestrial surface. Taken into consideration were to be only relatively young objects, 0 to 15 mln years old, so as to exclude errors due to possible continental drifts.

As it follows from the distribution map thus obtained, there are four regions of contemporary intraplate magmatism: two large ones, the Pacific and the African, and two smaller ones, the Central Asian and the Tasmanian. The largest (African and Pacific) measure 10,000 km across, and are comparable in size to the main lithospheric plates, though their boundaries do not concur with the contours of the regions.

The results of these studies are summed up in the article title "Intraplate Magmatism and Its Significance for an

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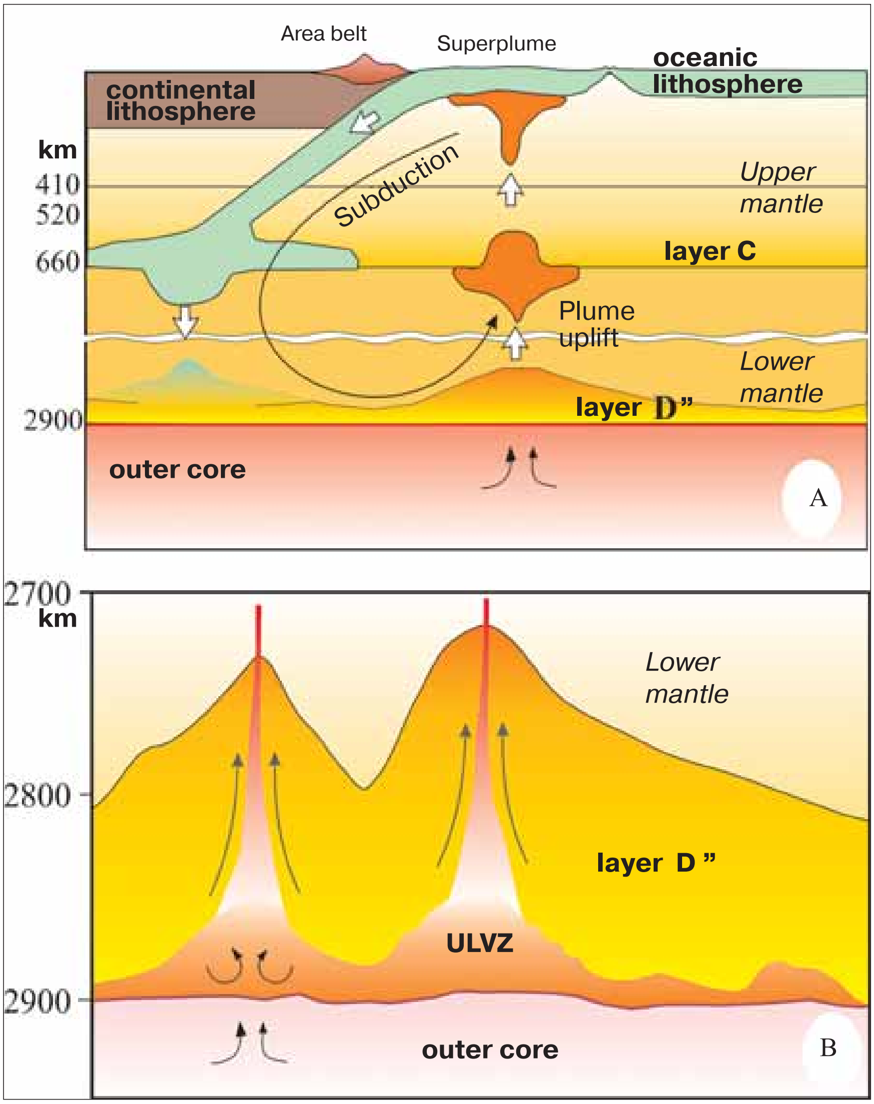
* Trap, a continental plateau composed of diabases, dolerites, basalts, gabbro-diabases and gabbro.—*Ed.*



The lithospheric (oceanic) plate sinks into the mantle (A). The greater part of the plate stays in the C layer, but some of the lithospheric material submerges down to the layer D” where a superplume originates (B).

Understanding of Processes in the Mantle of the Earth” (L. Sonenschein, M. Kuzmin, Geotectonics, 1983); the two authors designated the intraplate magmatism regions as hot fields of the earth. These were said to coincide with major positive anomalies in relief and also with positive aberrations of the geoid’s form. Judging by the geochemical characteristics of constituent rocks, material composition anomalies—possibly linked to the lower mantle—correspond to these regions.

Thus, the identified hot fields of the earth mantle could be visualized as upwelling regions for the substance and energy of the lower mantle, while the cold fields in between, as zones where the substance sinks into the mantle. In total a coordinated system of convective mantle flows stood out.

If processes associated with the upper earth shells could be described within the framework of lithospheric plate tectonics, the detection of hot fields pointed to the more plutonic nature of convective flows. That is to say, proceeding from the new evidence it became now possible to speak of an interconnection of processes in the lower and upper mantle. The narrow mantle jets related to the hot spots could be in the form of plumes* traveling from the lower/upper mantle interface to meet the heated matter of the lower mantle. It is these jets that give rise to interpolate magmatism and create the system of hot spots. We should note that these conclusions had been formulated before seismotomography entered the stage in the 1980s; its methods enabled earth scientists to get a better understanding of the mantle’s internal structure. Japanese and American scientists, for one, were able to detect large volumes of matter within the mantle related to higher and

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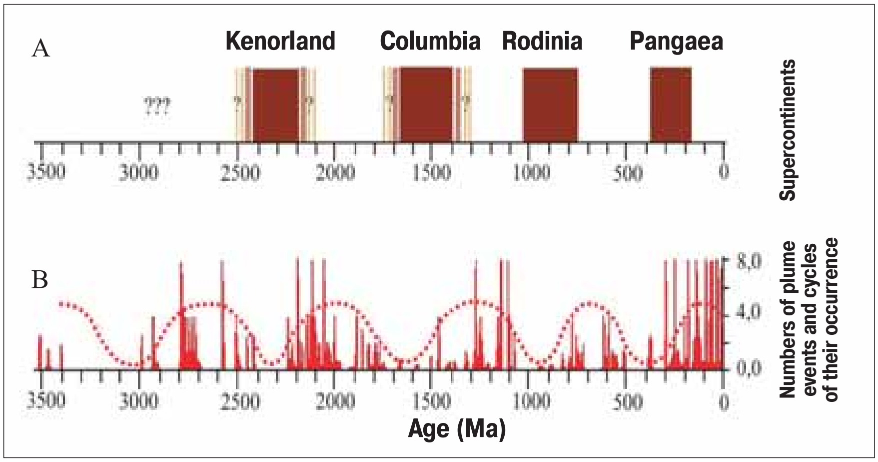
* Hot mantle jets traveling independently from convective flows in the mantle.—*Ed.*



At least four supercontinents are thought to have been in existence in the geological history of the earth. The time intervals of their origination and breaking under the effect of superplumes (A) have been determined. These events occur in cycles and correlate with plume activity (B) (Li, Zhong, 2009; Torsvik, 2004).

lower velocities of seismic waves. The principal conclusions of these studies boil down to the following: there are two large low shear velocity provinces (LLSVP), the African and the Pacific (also called superplumes today). Seismography data indicate the upwelling of D” plutonic matter. It is to be noted that the projections of LLSVP to the terrestrial surface coincide with the hot mantle fields established earlier.

In contrast to the low velocity provinces those of high velocity are confined to subduction zones where lithospheric plates plunge into the mantle. The subducted (absorbed) lithosphere stays in part at the upper/lower mantle boundary, while yet another portion of it submerges down to the core/mantle interface. The lithosphere substance getting into the D” layer, acted upon by heat emanating from the core, form partly molten masses begetting hot plumes rising to the earth surface. Such upswelling is conducive to expansion of the volume with the transition of postperovskite from the D” layer in the lower mantle to perovskite; it likewise activates the entry of volatile chemical elements, C, S, O, and H above all. As it follows from the differentials of the density of matter in the inner and outer core, these elements are contained in the outer core and are carried into the mantle where they are implicated in the formation of plumes. Thus, the notion of low and high velocity mantle provinces helps to link together two streams (jets): the plunging of cold matter into the lower mantle and the upwelling of hot jets to the terrestrial surface.

The conjugation of these flows in the mantle points to a tight connection of plutonic geodynamics with plume and plate tectonics. The interconnection of formative processes of supercontinents and superplumes in single cycles argues well for that. Today we know that supercontinents emerged in the process of earth evolution; these supercontinents bring actually all continental masses together. Subsequently such supercontinents were destroyed by superplumes, while the movements of separate continents became centrifugal. It is supposed that at least four supercontinents have been in existence in the geological history of the earth (Kenorland, Columbia, Rodinia and Pangaea).

INTRAPLATE MAGMATISM OF SIBERIA

Siberia was a component part of the Rodinian continent which came into being about a billion years ago but, about 250 mln years thereafter, started breaking apart under the action of the underlying Rodinian superplume. Simultaneously with the Rodinian superplume an antipodal plume was thought to be in existence. With Rodinia’s breakup the component continents, Siberia included, traveled into the region of the Late Rifean ocean.

Siberia was not large in those days, it comprised the Siberian Craton (platform) alone. Thereupon it took in folded orogenic belts, the Central Asian in the first place, and then the Kazakhstan and China continents; the closure of the Paleo-Urals ocean led to the creation of the vast Euroasian continent. All these processes were associated with plate tectonics setting the stage for small and large continental masses being joined to Siberia. This matter is considered in greater detail in the monograph authored by Leo Sonenschein, Mikhail Kuzmin and Lev Natapov—*Lithospheric Plate Tectonics in the Territory of the USSR* (1990).

Siberia is remarkable for many intraplate magmatic complexes. Large rock masses similar to OIB have been discovered out there. This means that about 600 mln years ago the ocean washing the Siberian continent had islands formed by hot spots. Such spots acted upon the continent as well to engender regions of intraplate magnetism. In practical terms all through the Phanerozoic*, up to the latest time (>25 mln years) the continent and its

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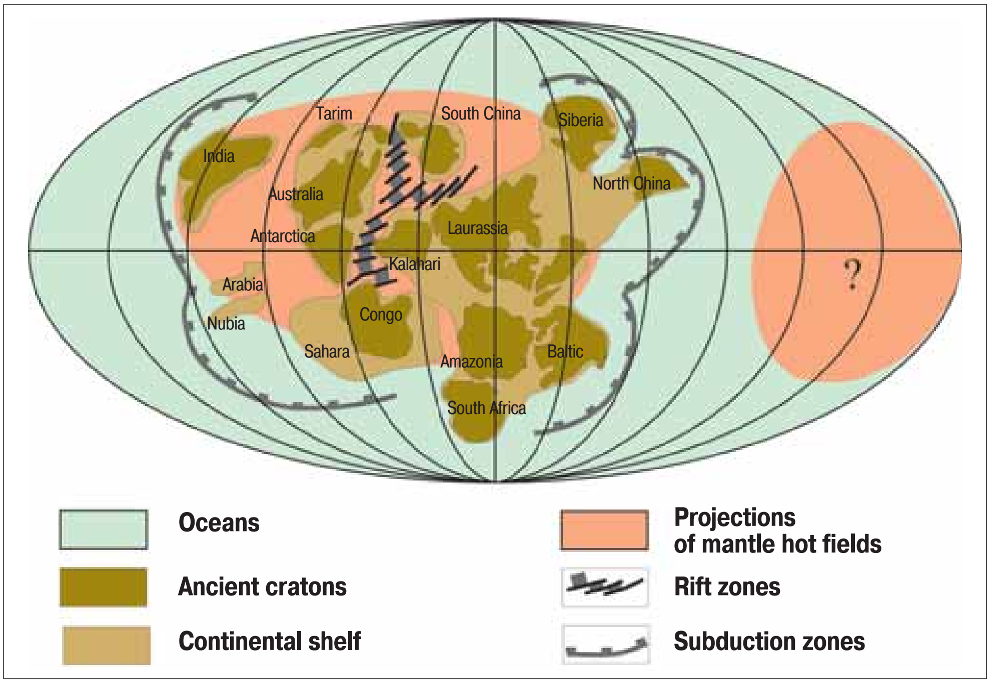
* A geologic epoch still on over these last 540 mln years, also known as the time of “visible” life (<Gr *phaneros*, or visible). It is broken down into three geological eras: Paleozoic (540-252 mln years ago) and Mesozoic (252-66 mln years ago); Cenozoic (66 mln years ago—Holocene, or recent period).—*Ed.*



Restoration of the Rodinian plume responsible for Rodinia's breakup (Li, Zhong, 2009). The antipodal superplume shown in the opposite sector of the earth.

ambient oceanic environment had been acted upon by a hot mantle field, the superplume (Yarmolyuk et al., 2006; Kuzmin et al., 2010). In the Early and Middle Phanerozoic (~540-360 mln years ago), after the disintegration of Rodinia, this led to the formation of two large magmatic provinces—the Altai-Sayan and the Vilyui. Later on (310-190 mln years) several other intraplate magmatic provinces were formed. One, the Barguzin, over $2x10^5$ km^2 large, is of zonal structure, with rift zones at the periphery, and the giant Angara-Vitim granitoid batholith in the center, over 0.5 mln km^3 large and formed due to an extensive melting of the crust under the thermal effect of the mantle plume.

A great event took place at the close of the Late Paleozoic within a geologically short span of time (3 mln years) in the North Asian continent: a giant magmatic province was formed there. It embraced the trap region of the Siberian platform and the rift system of Western Siberia; stretching over 1,500 km, it goes through the base of the West Siberian Lowland.

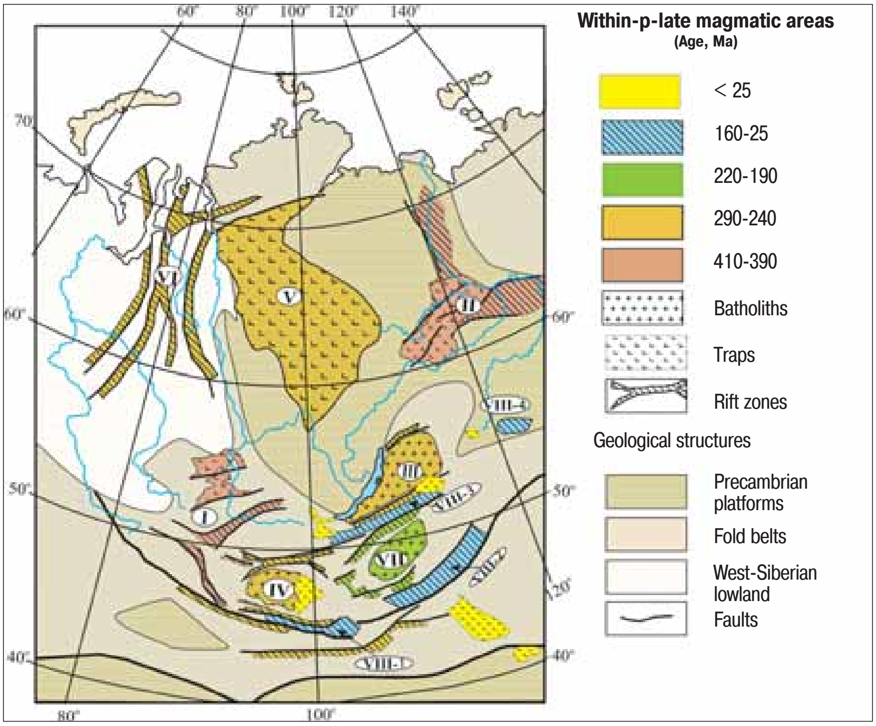
The same period also witnessed intraplate magmatism taking in the southern folded fringe of Siberia. Formed there were Tarim traps and the conjugated system of subparallel rift zones within Mongolia: those of Gobi-Tien-Shan and the Main Mongolian Lineasment (fracture). Two other rift systems—the Gobi-Altai and North Mongolian—correspond to the onward movement of the centers of plume magmatic activity deep into the Siberian continent. Simultaneously with the latter two rift zones, there appeared in between them a granitoid batholith (Khangai); its formation is also associated—like that of Angara-Vitim—with the melting of the crust above the mantle plume. The development of the rift system ended with the formation of the zonal Mongolian-Transbaikal magmatic area in the Early Mesozoic (~200 mln years ago).

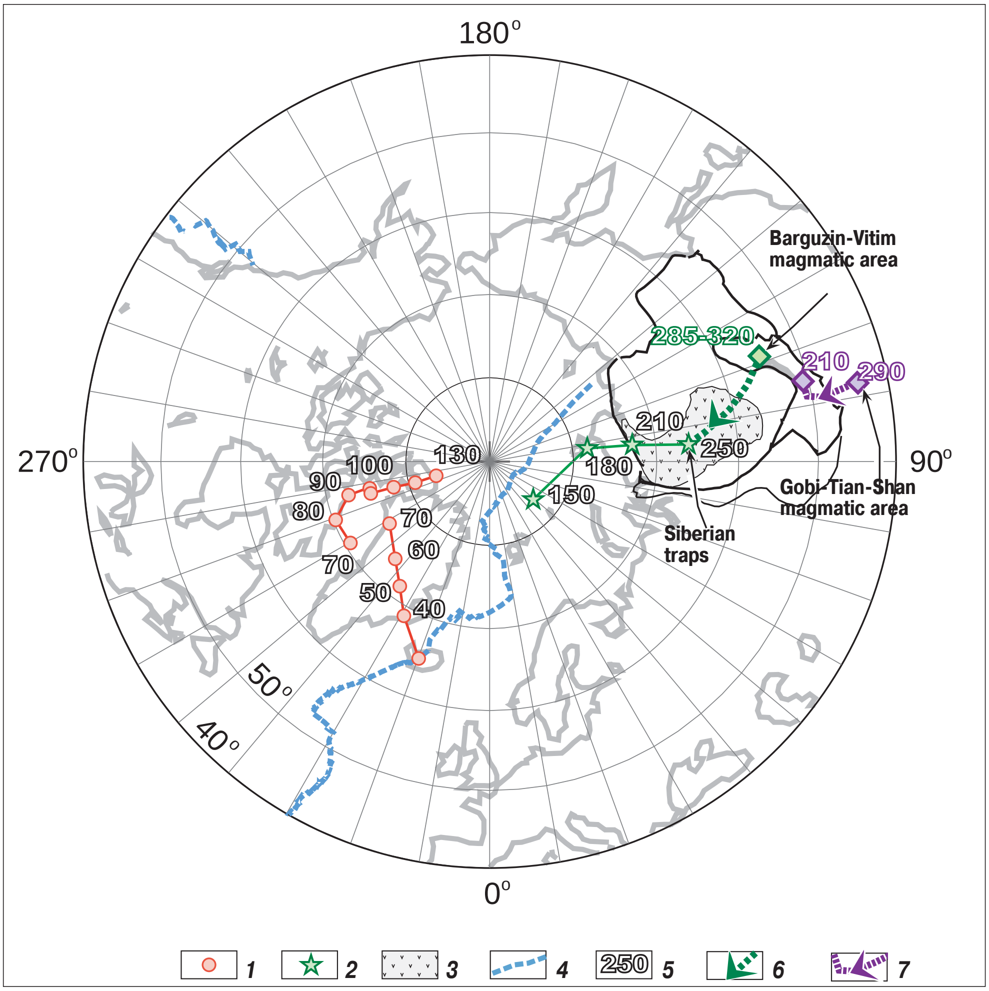
About 190 mln years ago the intraplate activity slowed down dramatically. However, in the Late Mesozoic the action of mantle plumes on the lithosphere of the Siberian continent resumed, with several rift regions emerging within the limits of the Central Asian area of the Siberian platform. The climax of tectonic and magmatic activity concurred with the onset of the Cretaceous period (145 mln years ago). In subsequent periods this activity fell off.

Yet another "outburst" of such activity occurred in the Late Cenozoic (<25 mln years ago) covering the territory of Central and Eastern Asia. New volcanic areas took body and form (South Baikal, Udokan, Vitim, among others) in the wake of the birth of hot spots (Kuzmin et al., 2010).

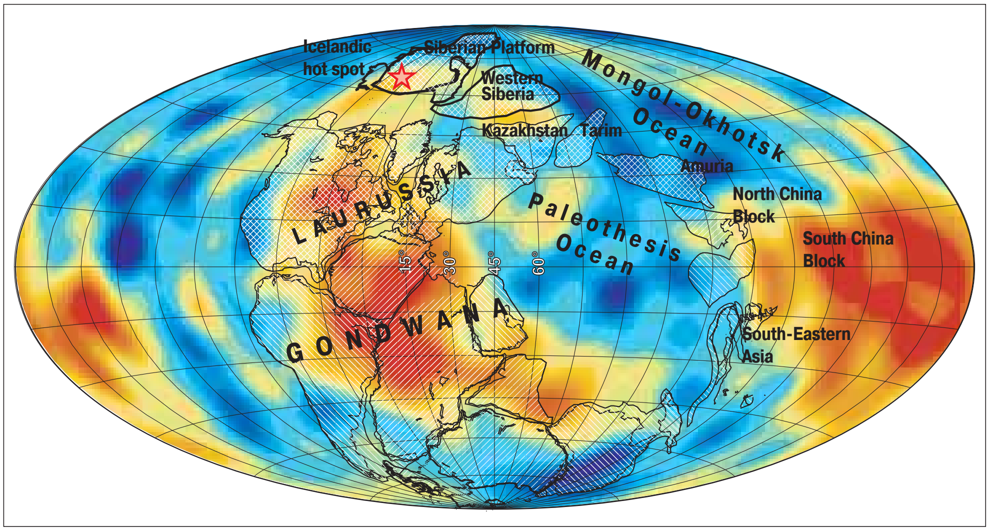
In order to understand the scenario of Siberia's interaction with hot spots, and how these are linked to the earth's plutonic structures we need "absolute" paleoreconstructions in line with present-day geographical coordinates. We attempted such kind of reconstruction in our article published in the *Earth-Science Reviews*, 102 (2010). Our results made it possible to answer certain questions related to the role of plumes in the geological history of our planet and in particular, that of the hot spots of the mantle.

Products of oceanic type magmatism persist in the structures of the Siberian paleocontinent thus indicating the activity of the African superplume. Large eruptive provinces: Early-Middle Paleozoic: I—Altai-Sayan; II—Vilyui, Late Paleozoic; III—Barguzin-Vitim; IV—Central Asian, Permotriassic; V—Siberian traps, Early Mesozoic; VI—West Siberian rift system, Late Mesozoic-Cenozoic rift systems; VII—East-Mongolian transBaikal system; VIII(1)—South-Khanga (Gobi-Altai), VIII(2) East Mongolian, VIII(3)—West-transBaikal, VIII(4)—Central Aldan (Yarmolyuk, 2000, 2003, 2006, modified).





Migration of the Icelandic hot spot in the Arctic basin in the present geographical coordinates:
1—not later than 130 mln years ago,
2—from 150 to 250 mln years ago,
3—Siberian traps,
4—mid-ocean ridges,
5—magmatism age in millions of years,
6—migration of magmatism, connected with Siberian plume,
7—migration of magmatism, connected with Hangai plume (Kuzmin, 2010, Kharin, 2000 et al.).



Reconstruction of the Siberian platform and continents over 250 mln years. Shown beneath the continental contours is the propagation of LLSVP close to the core/mantle interface. Bright red, the upswelling of hot mantle matter, blue—the sinking of relatively cold matter. The lay of the basic LLSVP regions is considered rather stable over a long stretch of geological time.

A DRIFT 570 MLN YEARS LONG

The continual intraplate magmatic activity on the Siberian continent shows it to be located within the bounds of a mantle hot field, at least from the Ordovician on to the Cretaceous, or for as long as 490-470 mln years. To carry out "absolute" paleoreconstructions of Siberia we must know the paleographic position of magmatic regions in the Late Paleozoic and in the Early Mesozoic (more than 250 mln years ago).

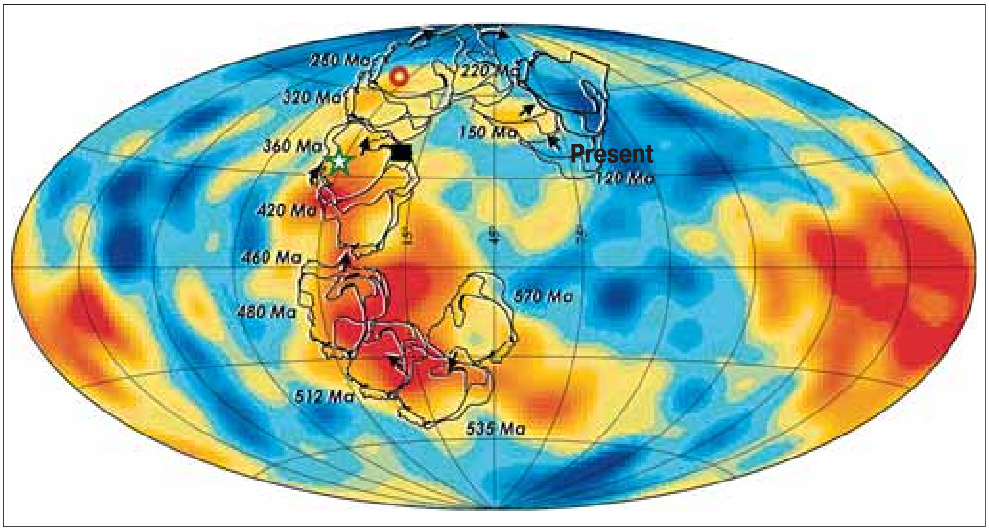
The traces of the magmatic activity of the Icelandic hot spot in the Late Mesozoic and in the Early Cenozoic are seen in the North Atlantic and in Greenland (these data are summed up in our work (Kuzmin et al., 2010)). So, hot spot traces are impressed in the lithosphere of migrating continental blocks of the Arctic basin for the last 250 mln years.

The coordinates of the Icelandic hot spot: 65 °N and 342 °E. The paleolatitude of the Siberian trap province during its formation (250 mln years ago) was in practical terms the same as that of Iceland today (62°±7°). At any rate all through the Permian and the Triassic this very hot spot was situated above the northern extremity of the African hot mantle field. Since this field has persisted in the static coordinates over these last 300 mln years (Torsvik et al., 2008), we infer that Siberia remained therein throughout the Phanerozoic. Signs of extensive intraplate magmatic activity in Siberia demonstrate that the Siberian continent was drifting over the hot mantle field at least from the epoch of the Early Paleozoic up to the Permian/Triassic period. Which means that Siberia's longitudinal position did not see any dramatic changes, even though its paleolatitudinal position was changing. Like today the African hot field was situated approximately between 70° and 330 °E, that is this continent did not go beyond these limits from the Early Phanerozoic prior to the Permian and the Triassic. Since the then position of Siberia and the present position of the Icelandic mantle plume coincide, we are able to determine the geographical coordinates of the Siberian continent in the past. During the Vendian-Early Cambrian periods it was situated near the equator, with its present southern and southeastern boundary oriented northward. We (Kuzmin et al., 2010) designated the old (paleo) latitude 30° for the Siberian Cambrian within the African hot mantle field so as to minimize the shifts of the Siberian continent within this field and exclude dramatic migrations of the continent at velocities higher than those of the present continental drift.

In the Early Cambrian (~537 mln years ago) Siberia lay in the Southern Hemisphere (30 °S, 20 °E). Beginning in the middle of that period (520-505 mln years ago) up to the Early/Mid Ordovician it drifted northward as far as the equatorial latitudes. The rate of its latitudinal drift 512 to 480 mln years ago was 5 cm/yr (finite velocity for present continental plates), and thus there could not be any significant changes in longitudinal transpositions.

The intraplate magmatic events in the Siberian continent were connected from the Cambrian (510 mln years ago) on to the Permotriassic (250 mln years ago) when Siberia was moving over the African hot field. By paleomagnetic evidence in the Early Paleozoic Siberia drifted north at the mean rate of latitudinal transposition about 7.3 cm/yr. This continental drift velocity is rather high, which means Siberia was moving latitudinally along the meridian, i.e. the longitudinal migration did not change greatly.

In their paleoreconstruction (Kuzmin et al., 2010) the authors put the Russian and the Siberian platforms above the African hot field since the dramatic magmatic events of the Devonian occurred on both platforms (Viluian rift in Siberia, and the Pripet-Donets rift in Europe).



Paleoconstruction of the migration of the Siberian continent over the African mantle province within the last 570 mln years (Kuzmin, 2010).

After the Devonian Siberia migrated north, simultaneously turning 60° clockwise (360-250 mln years ago), i.e. before it reached the Icelandic hot spot. The latitudinal migration velocity averaged about 4 cm/yr, which is consistent with the present rates of the continental drift. In the time stretch of 250 to 200 mln years ago Siberia departed from the Icelandic hot spot. This departure was caused by the opening of the North Atlantic. In the Late Mesozoic intraplate magmatic activity moved to Central and Eastern Asia, and it shrunk considerably by the end of the Cretaceous. In these last 250 mln years the Siberian continent migrated to its present position, drifting latitudinally across the North Pole at 1.7 cm/yr.

Summing up, let us stress this point: the earth is a self-organizing system whose further evolution is tied in with the interaction of its internal shells, namely with convection processes and mantle plumes. Now we know that the upwelling mantle jets are mainly concentrated in two areas set off as superplumes, the Pacific and the African. Their role in the formation of the lithospheric structure can hardly be overestimated. Hence the pertinent question: when were superplumes born and why? How long is the life span, and how stable is their action on the lithosphere?

The authors of the present article have made a certain contribution in clearing these matters. To begin with they demonstrated that the shows of intraplate activity on the Siberian continent throughout the Phanerozoic came as a followup of its migration over the hot field; such manifestations are comparable to the present African superplume. This superplume has been alive for no less than 570 mln years. What with the Rhodinean superplume that smashed Rodinia being compared to the Pacific plume (Yuen et al., 2002), both should be considered to be the most long-living structure of the earth.

The tie-in of superplumes with processes implicated in the formation and breaking up of supercontinents is now universally accepted. Yet the latest evidence allows us to say that the fragments of supercontinents upon their destruction by the killer superplume are migrating into regions controlled by the antipodal plume to form a new supercontinental agglomeration. This dual role of the plumes must be reflecting their antiphasic activity associated probably with different shows of responding convective processes. As demonstrated by Acad. Vyacheslav Kovalenko and colleagues, the thermostatic effect could be one of the causes of this phenomenon.

Now about the future research prospects. Separate continents (Siberia) passing above the hot spots of a particular hot field of the mantle and involved in a supercontinent's formation, say of Pangaea or Eurasia, keep races of these hot spots. This fact allows us to suppose: already in the near future the available methods of studies into magmatic rocks will help to evaluate the evolution of mantle sources both for individual plumes and for superplumes at large. Ultimately this will contribute to a further understanding of the general laws of the evolution of the earth.

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