Parameters of magma chambers

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Abstract. The Earth’s early (“pregeological”) thermal history has been reviewed, and primordial conditions of the tectonosphere’s thermal evolution during the subsequent period (4.2 to 0.0 billion years ago) have been formulated. It is shown that periodic displacement of the material in volumes measuring about 120±60 thousand km³ or in n-fold amounts are inevitable. The mantle advection parameters make it possible to forecast depths of magma chambers and temperatures within them, something that can be corroborated by experimental data.

1. Introduction

The pattern of heat and mass transfer according to the advection-polyomorphic hypothesis (APH) during active processes suggests that of floating asthenolites (quanta of tectonic action - QTAs) occur at identical depths in all cases of endogenous processes. They differ in the sequence of their rise to the top. In order to explain the composition of magmas being melted out and the heat flows (HF) at different stages of the process, it is necessary to assume that magma chambers, initially emerging beneath geosynclines, had their top portions at depths of 220-250 km (prior to the start of the QTA), then at 160, 100, and 40 km. The sequence is inverse in the case of rifts. In zones of single-episode active processes with a small initial partial-melting reservoir in the lower part of the upper mantle, it is likely that the material first rises to a depth of 220-250 km and then to beneath the crust. When a recently completed geosynclinal or rifting process gets under way again, the relic asthenosphere with a shallow (about 100 km) depth of the top portion goes for the formation of a QTA.

Crustal magma chambers are predicted to occur at depths somewhat greater than 20 km with sporadic intrusions of secondary magmas to depths of up to 6-10 km (figure 1).

To verify this hypothetical model, we used information on the position of interfaces in the upper mantle, interfaces that took shape above magma chambers in the form of zones of repeatedly metasomatically altered rocks, the data on depths from which kimberlites and alkaline basalts transported xenoliths, and on depths of the magma chambers according to the composition of igneous rocks. A small amount of data on the depths of magma chambers in the crust and beneath the crust were used in accordance with the Curie temperature of titanomagnetites in young igneous rocks.

The data on magma chambers as predicted by the hypothesis and those derived by independent geological and geophysical techniques are in virtually full agreement. Therefore, numerical verification in terms of the said parameter can be viewed as accomplished.

It is, however, necessary to analyze not just depths but also temperatures in the top portions of magma chambers, as well as possible changes in PT parameters with the age or with type of endogenous conditions. We found the use of the correlation between composition of igneous rocks and parameters of the magma chamber, as proposed by Gordienko, to be suitable for tackling this problem. The listed publications contain a vast bibliography pertaining to rock composition. It will not be replicated in this paper for reasons of space.
Figure 1. Histograms showing distribution of parameters of magma chambers. 
A-C – depths of the top portions: A – for the Transcarpathian trough, based on Curie temperatures of titanomagnetite; B – based on xenoliths transported by kimberlite and alkaline-basic magmas (B₁); according to majorite inclusions in diamonds (B₂); C – based on upper mantle velocity profiles, primarily for Northern Eurasia.

To achieve the stated goal, we need a technique for express analysis of information on the composition of rocks that originated in the mantle, a technique that would make it possible to process dozens of thousands of analytical results. To begin with, several methods based on the use of numerous data on rock composition were employed. Then, based on the results published, we managed to confine our calculations to using concentrations of two oxides. Determinations of the depth of the magma chamber top portion (H) and temperature (T) in it were performed with the SiO₂ content not exceeding 52 percent (i.e., for basic and ultrabasic rocks); carbonatites and formations with large concentrations of elaeolites (i.e., not just elaeolite syenites, but also phonolites, etc.) were disregarded. Contents of Al₂O₃ and MgO were used. As shown on thousands of examples of PT parameters’ determinations for magma melts, those values reflect them particularly accurately (see figures 2 and 3). The following formulas were used: 

\[ T = -0.365(MgO)² + 32.903(MgO) + 1,060 \]

\[ H = 0.319(T - 1,050) \]

These formulas turn out to be essentially linear for the upper half of the upper mantle: 

\[ H = 0.33(T - 1,060) \]

and very close to that shown above. At large values of Al₂O₃ concentrations, the formula yields clearly underrated temperature values and, accordingly, underrated depths of magma chambers. For that reason, at concentrations of 22 percent and higher, a constant value of \( T = 1,070°C \) was used which, in the case of commonly encountered concentrations, could not appreciably affect the results. MgO concentrations below 1.5 percent were not used either.

There were attempts to use in the calculations a relationship between calcium oxide concentration in igneous rocks of mantle origin and the depth and temperature of the magma chamber. They proved to be less successful than those for aluminum and magnesium oxides.

The opportunity of using large datasets presented in Geokem has made it possible to clarify the cause of that phenomenon and provide even more sound grounds for ruling out the use of calcium concentrations (figure 2). Other oxides are even less suitable.

A comparison between estimated parameters and those derived for the same rocks with the help of a detailed mineralogical analysis based on published evidence from geothermometry and geobarometry studies shows that errors in the methods being compared are similar in magnitude. A shortcoming of this approach is the need to actually coordinate the results with the adopted solidus line. This leads to an appreciable reduction in temperature variations at a single estimated depth.

We get a depth range stretching for several extra kilometers. A specific version of such “stretching” is also shown at the bottom of figure 3.
Figure 2. Relationship between concentrations of magnesium, aluminum, calcium, sodium, iron, and titanium oxides for rocks of the Hawaii Islands (A) and Australia’s Yilgarn Shield (B). The line marks the type of relationship deduced from evaluation formulas.

Figure 3. Illustration of deviations of $\text{Al}_2\text{O}_3$ and MgO relationships in real rocks of dissimilar age in several oceanic and continental (dots) regions from those assumed on the basis of calculation formulas (line). A) Azores Islands, Jan Mayen Island, and Reunion Island; B) Polynesia; C) Kamchatka; D) Urals; E) Baltic Shield. Shown in the insert is a histogram of deviations from the average of estimated temperatures according to Figs. 11, 12, and others.
Actual errors amounting to several dozens of degrees and about 10 km for rocks of mantle origin noticeably exceed those resulting from the calculation technique proper. Their values can, for example, be assessed on the basis of comparison between magnesium and aluminum oxides’ concentration relationships as derived from calculation formulas and those observed in reality (figures 2 and 3). The obtained ΔT values reflect differences between temperatures calculated in terms of concentrations of each of the oxides. The listed results are the mean values of the parameter in question (a typical deviation from them is about 40°C). The scatter of oxides’ concentrations shown in figures 2 and 3 characterizes its value as close to optimal. It can be smaller or larger within large enough datasets used.

To differentiate between large datasets provided in Geokem, we used, whenever possible, arrays of analyses attributed to specific rocks. A relatively small spread of oxide concentration values in the area of basic rocks with maximum silica contents resulted, in some cases, in information arrays in which characteristics of two foci, most frequently closest to the surface, merged. As shown above (figure 1), it is important to think in terms of the limited thickness of a real melting focus in the mantle. Conversely, broad ranges of variation of large MgO concentrations in ultrabasic rocks (as shown in figure 1 for wehlrites and dunites: 33–46 percent) do not cause any significant variations in the estimated H and T – just at the level of calculation error (figure 3: 10 km and 40°C).

Figure 4. Sites from which rock samples used in this study were collected.

Despite these and other shortcomings, the large amount of material used and the wide range of endogenous conditions have enabled us to obtain credible results.

To address the task, we invoked results of compositional analyses of magmatic rocks that originated in the mantle beneath dry-land territories and marine areas of all continents and oceans. Their total number is about 70,000, and 30,000 of them were collected in oceans. Figure 4 shows the location of sampling sites.

2. Oceans

It was shown on the basis of geological and geophysical evidence that the plate tectonics hypothesis is not applicable to any oceans and that the continental crust may have undergone oceanization relatively recently (since the Mesozoic). The data for all mid-ocean (seismic) and the majority of aseismic ocean ridges were used in the analysis (figure 4). Results characterizing the entire batch of magma chambers’ “levels” could not be obtained for some regions covered by studies. In all likelihood, however, this is due to the specifics of exploration maturity. Nevertheless, the existence of the deepest-seated (215±15 km) magma chambers has been corroborated (table 1), as well as of those at intermediate depths (145±15 km and 85±5 km), and of the shallowest magma chambers (55±5 km). In some cases, results of magma material transport to the subsurface chamber at the depth of 30±5 km could be discovered.

Atlantic Ocean islands that have been covered by studies are not put in a separate category because they are situated on the shelf.
On the whole, it is obvious that the derived depths of magma chambers and temperatures in them match those predicted and do not point to any appreciable differences in parameters between oceanic regions.

**Table 1. PT parameters of magma chambers in the mantle beneath oceans (the depth in km and the temperature in °C).**

| Regions            | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|--------------------|---------|---------|---------|---------|---------|
| Pacific Ocean      |
| MOR                | -       | -       | 90; 1,300| -       | -       |
| Aseismic ridges    | -       | 120; 1,400| 85; 1,300| 65; 1,250| -       |
| Plateau, Shelf     | 230; 1,800| -       | 80; 1,300| 55; 1,200| -       |
| Basins             | 230; 1,800| 190; 1,650| 80; 1,300| 55; 1,200| 25; 1,150|
| Islands            | 200; 1,700| 145; 1,500| 95; 1,500| 65; 1,250| 30; 1,150|
| Trenches           | 210; 1,700| 130; 1,450| 85; 1,300| 65; 1,250| 40; 1,200|
| Peripheral seas    | -       | 130; 1,450| 90; 1,350| 60; 1,200| 40; 1,150|
| Atlantic Ocean     |
| MOR                | 230; 1,800| 140; 1,500| 95; 1,350| 55; 1,250| 25; 1,100|
| Plateau; Shelf     | 220; 1,750| 150; 1,550| 90; 1,350| 55; 1,200| 30; 1,150|
| Islands            | 210; 1,700| 140; 1,500| 95; 1,350| 55; 1,200| 35; 1,150|
| Peripheral seas    | -       | 140; 1,500| 80; 1,300| 55; 1,200| 25; 1,100|
| Trenches           | -       | 145; 1,500| 100; 1,350| -       | -       |
| Indian Ocean       |
| MOR                | -       | 150; 1,550| 90; 1,350| 55; 1,250| 25; 1,100|
| Aseismic ridges    | -       | -       | 85; 1,300| 50; 1,200| 30; 1,150|
| Basins             | -       | -       | 85; 1,300| 55; 1,200| -       |
| Islands            | 190; 1,650| 140; 1,500| 90; 1,350| 55; 1,350| 30; 1,150|
| Arctic Ocean       |
| MOR                | 215; 1,700| 140; 1,500| 100; 1,350| 70; 1,300| 45; 1,200|
| Aseismic Ridge     | -       | -       | -       | 70; 1,250| 30; 1,150|
| Plateau; Shelf     | -       | 170; 1,600| 90; 1,350| 75; 1,300| 50; 1,200|
| Basins             | -       | 120; 1,400| 95; 1,350| 75; 1,300| 55; 1,250|

3. Eurasia

In the dataset pertaining to continents, Eurasia stands out both in terms of the quantity of information and diversity of zones studied that have displayed dissimilar endogenous conditions. It makes sense to discuss the relevant results separately.

The materials on Eurasia can be used to analyze the issue of variation of magma chamber parameters with age, both in the Precambrian (as suggested, for example, by Svetov et al., 2003) and in the Phanerozoic, as well as their differences for geosynclines, rifts, and zones of single-episode active processes.

The data on Eurasia were divided into groups according to the type of endogenous conditions. When the volume of information within the groups was sufficiently large, regional or age-related subgroups could be identified.

Magmatism in Eurasian geosynclines of dissimilar age is rather unevenly represented in the dataset. Information on regions with folding of Caledonian and Cimmerian age is insufficient for attributing individual characteristics to them. For that reason, the data on the former were added to the dataset on Hercynides and the data on the latter – to Alpides.

The tables shown below contain recurring names of regions. This happens in cases when different selections of analyses, largely those quoted from different publications, are used in the analysis. Sometimes they refer to stages of geological history differing in age or in type of endogenous
conditions. The assumption on the change of magma chambers’ parameters with the age of geosynclines is considered on the basis of data provided in table 2.

It is obvious that no such correlation can be spotted, the differences between parameters are insignificant, and the changes are irregular. This is also corroborated by other evidence quoted below. Information on shallowest (crustal) chambers was not considered since they are often inaccessible in the case of Precambrian geosynclines due to the level of erosional truncation.

Table 2. PT parameters for magma chambers in Eurasian geosynclines of dissimilar age

| Region, age of folding | Parameters of magma chambers (H in km; T in °C) |
|-----------------------|-----------------------------------------------|
|                       | Level 1 | Level 2 | Level 3 | Level 4 |
| Ukrainian Shield, Archean (Sursky greenstone structure) | 220; 1,750 | 155; 1,550 | 95; 1,350 | 55; 1,200 |
| Ukrainian Shield, Proterozoic (Krivoy-Rog-Kremenchug zone) | 225; 1,750 | 170; 1,550 | 85; 1,300 | 55; 1,200 |
| Tien-Shan, Hercynides | 210; 1,700 | 150; 1,500 | 85; 1,300 | 60; 1,200 |
| Crimea, Cimmerides | 195; 1,650 | 165; 1,550 | 80; 1,300 | 50; 1,200 |
| Carpathians, Alpides | 210; 1,750 | 140; 1,500 | 90; 1,350 | 50; 1,250 |

Yet, we can analyze information on several Cimmerian and Alpine geosynclines for which relatively meaningful datasets have been put together (table 3).

Table 3. PT parameters of magma chambers in Eurasian Alpine and Cimmerian geosynclines

| Region | Level 1 | Level 2 | Level 3 | Level 4 |
|--------|---------|---------|---------|---------|
| Sikhote Alin | 210; 1,650 | - | 75; 1,300 | 55; 1,200 |
| Honshu and Ryukyu | - | - | 90; 1,300 | 50; 1,200 |
| Lesser Caucasus | 210; 1,650 | - | 100; 1,350 | 55; 1,200 |
| Rodopes | 220; 1,750 | 135; 1,450 | 105; 1,350 | 55; 1,200 |
| Komandor and Aleutian Islands | 195; 1,650 | 155; 1,550 | 100; 1,300 | 55; 1,200 |
| Kamchatka and Koryakia | 215; 1,750 | 155; 1,550 | 90; 1,300 | 55; 1,200 |
| Sakhalin | 230; 1,800 | - | 100; 1,350 | 50; 1,200 |
| Chukotka | 230; 1,750 | - | 80; 1,300 | 55; 1,200 |
| Kuriles | - | - | 95; 1,350 | 55; 1,200 |
| Bonin, Marianas, and Solomon arcs | 170; 1,500 | 130; 1,450 | 85; 1,300 | 55; 1,200 |
| Philippines | - | 130; 1,450 | - | 50; 1,300 |
| North Vietnam | - | 125; 1,450 | 95; 1,350 | 50; 1,200 |
| Sulaiman-Dag | - | - | - | 40; 1,150 |
| Elburs | - | 123; 1,450 | 100; 1,350 | 50; 1,200 |
| Zagros | 190; 1,650 | 170; 1,580 | 110; 1,400 | 50; 1,200 |
| Tibet | - | - | 80; 1,300 | 45; 1,200 |
| Taurus | - | - | 85; 1,300 | 55; 1,200 |
| Appenines and Corsica | - | 150; 1,500 | 85; 1,300 | 55; 1,200 |
| Pindos | - | 145; 1,500 | 90; 1,300 | 55; 1,200 |
| Cyprus and Syria | - | 150; 1,500 | 85; 1,300 | 65; 1,250 |
| Himalayas | - | - | 90; 1,300 | 65; 1,250 |

A considerable part of the datasets turned out to be comprised of uniform analyses pertaining to just a limited depth range of magma chambers’ locations. In other regions, however, all levels are discernible. More often, melts from crustal sources are represented by acid and intermediate rocks, and for that reason the uppermost level is not included in the table.
Approximately the same applies to Caledonian and Hercynian geosynclines in Eurasia (table 4), but in this case the upper level has, after all, clearly manifested itself in magmatic rocks of mantle origin.

The data on Norwegian Caledonides and on the Hercynides of the Rheno-Hercynian zone do not contradict those listed in the table, but are limited to just one chamber depth.

**Table 4.** PT parameters of magma chambers in Eurasia’s Caledonian and Hercynian geosynclines

| Region; Age of folding | Level 1   | Level 2   | Level 3   | Level 4   | Level 5   |
|------------------------|----------|----------|----------|----------|----------|
| Central Asian* Caledonides and Hercynides | -        | 140; 1,500 | 90; 1,300 | 55; 1,200 | 30; 1,150 |
| Kolyma zone of Hercynides | 210; 1,700 | -        | 110; 1,400 | 65; 1,250 | -        |
| Western Siberia, Hercynides | -        | -        | 115; 1,450 | 70; 1,250 | 35; 1,150 |
| Tien-Shan, Caledonides and Hercynides | 220; 1,750 | 145; 1,500 | 115; 1,400 | 70; 1,250 | 45; 1,200 |
| Timan, Hercynides | -        | -        | 100; 1,350 | 70; 1,250 | 10; 1,100 |
| Urals, Hercynides | 230; 1,750 | 145; 1,500 | 95; 1,350 | 70; 1,250 | 35; 1,150 |
| Donets Basin, Hercynides | -        | 160; 1,550 | 100; 1,350 | 50; 1,200 | -        |
| Altai, Hercynides | 190; 1,650 | -        | 100; 1,350 | 65; 1,250 | -        |
| Sikhote-Alin, Hercynides | 215; 1,700 | -        | 90; 1,300 | 55; 1,200 | 25; 1,150 |
| Caucasus, Hercynides | 210; 1,700 | 160; 1,550 | 90; 1,300 | 65; 1,250 | 40; 1,150 |
| Western Kamchatka, Hercynides | -        | 145; 1,500 | 100; 1,300 | 75; 1,300 | 45; 1,200 |

*Altai, Transbaikalnia, Eastern Kazakhstan, Zaisan, Western Mongolia, Tien-Shan, Tyva, Kuznetsk Basin, Kuznetsk Alatau, Mountainous Shoria

The only scenario of endogenous conditions under which the deepest-seated magma chambers in the upper mantle may not manifest themselves (typical H not exceeding 100-150 km) is exemplified by contemporary active processes involving Alpides (and Late Cimmerides of the Pacific zone) (table 5). For folding with ages ranging from 30 to 60 million years, heat and mass transfer may start following:

restoration of a small zone of partial melting in the lower portion of the upper mantle. The material is initially transported to under the crust, and then, in the case of recurrent advection (its probability at the present stage of APH formulation is not yet clear), the heat-penetration zone and a small extent of partial melting may cause the material to spread down to 140-150 km depths. In the case of Late Alpides, heat and mass transfer uses partially molten matter of the primary asthenolense to transport the material directly to under the crust and into the crust. The depths of the magma chambers are unlikely to exceed 100-150 km.

**Table 5.** Recent active events in geosynclines with dissimilar ages of folding

| Regions          | Level 2 | Level 3 | Level 4 | Level 5 |
|------------------|---------|---------|---------|---------|
| Alpides and Cimmerides* | 140; 1,500 | 100; 1,350 | 75; 1,300 | 50; 1,200 |
| Caledonides and Hercynides | -       | 90; 1,300 | 75; 1,300 | 50; 1,200 |
| Caucasus         | -       | 90; 1,300 | 70; 1,250 | -       |
| Central Europe** | 135; 1,450 | 105; 1,400 | 80; 1,300 | 50; 1,200 |
| Rhine Graben and Massif Central | -     | 110; 1,400 | 85; 1,300 | 55; 1,200 |
| Central Spain    | 120; 1,450 | 100, 1,350 | -       | -       |
| Northwestern Tien-Shan | -       | 150; 1,400 | 75; 1,300 | 45; 1,200 |

*Verkhoyansk– Kolyma system, Kuriles (islands Paramushir, Shikonan, Iturup, and Kunashir), Komandor Islands (Bering island), Betic Cordillera, South-Western China,
Vietnam, Cambodia, Thailand, Southern Carpathians, Balkanides, Pannonia; **Bohemia, Thuringia, Saxony, and Silesia

Table 6. PT parameters of magma chambers in Eurasian* rifts of dissimilar ages

| Age                  | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|----------------------|---------|---------|---------|---------|---------|
| Riphean and Vendian  | 195; 1,650 | 140; 1,500 | 90; 1,350 | 60; 1,250 | 35; 1,150 |
| Paleozoic            | 215; 1,700 | 165; 1,550 | 90; 1,350 | 55; 1,200 | -       |
| Cenozoic             | 230; 1,750 | 165; 1,550 | 85; 1,300 | 60; 1,250 | 10; 1,100 |
| Contemporary rift    | - 145; 1,500 | 90; 1,350 | -       | -       | -       |

*Orsha Trough, Anabar Shield slope, Northeastern Mongolia, Kuznetsk Basin, Dnieper-Donets Depression, Western Siberian Plate, Tunguska Synclise, Siberian Platform, Baikal, Baikal Lakeside, Arabian Platform, Jordanian Rift, Sikhote-Alin, and Iceland.

The datasets collected for rifts of about the same age have made it possible to detect almost all deep-seated levels of magma chambers. In this case too there is every reason to conclude that there is no appreciable dependence of their depths and temperatures on the age of the process. The data on specific regions listed in table 7 point to the same finding. Table 7 also lists information on magmatism in various regions of eastern and southeastern Asia for which the data available to this author do not always enable determination of the type of endogenous conditions. It cannot be ruled out that some of the provided information pertains to single-episode active events, rather than rifting.

Table 7. PT parameters of magma chambers in Eurasian rifts

| Region                  | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|-------------------------|---------|---------|---------|---------|---------|
| Korea                   | -       | -       | 90; 1,300 | 65; 1,250 | 20; 1,100 |
| Inner Mongolia          | -       | -       | -       | 70; 1,250 | 45; 1,200 |
| Southeastern China      | - 145; 1,500 | 100; 1,350 | 70; 1,250 | 45; 1,200 |
| Emeishan                | - 135; 1,450 | 100; 1,350 | 70; 1,300 | -       |
| Tibet                   | -       | -       | 95; 1,350 | 70; 1,300 | 30; 1,150 |
| Taiwan                  | -       | -       | 100; 1,350 | 80; 1,300 | 55; 1,200 |
| Deccan                  | - 140; 1,500 | 105; 1,400 | 75; 1,300 | 45; 1,200 |
| Urals                   | 180; 1,600 | 125; 1,450 | 100; 1,350 | 75; 1,300 | 45; 1,200 |
| Chukotka                | - 125; 1,450 | 100; 1,350 | 70; 1,300 | 50; 1,200 |
| Norilsk                 | 175; 1,600 | 150; 1,500 | 100; 1,350 | 80; 1,300 | -       |
| Stanovoi Range          | -       | -       | 95; 1,350 | 75; 1,300 | 55; 1,200 |
| Baltic and Ukrainian shields | 140; 1,500 | 95; 1,350 | 80; 1,300 | -       |

Table 8. PT parameters of magma chambers in Eurasian Precambrian massifs

| Region; Age            | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|------------------------|---------|---------|---------|---------|---------|
| Ukrainian Shield, Archean | 210; 1,700 | 155; 1,550 | 95; 1,300 | 70; 1,250 | 35; 1,150 |
| Ukrainian Shield, Proterozoic | 195; 1,700 | 140; 1,500 | 95; 1,350 | 65; 1,250 | 25; 1,150 |
| Voronezh Crystalline Massif, Archean | 190; 1,600 | 120; 1,450 | - | 65; 1,250 | 20; 1,100 |
| Baltic Shield, Archean  | 205; 1,700 | 155; 1,550 | 105; 1,400 | 65; 1,250 | 20; 1,100 |
| Baltic Shield, Proterozoic | 205; 1,700 | 150; 1,500 | 95; 1,300 | 75; 1,300 | -       |
| Aldan Shield, Archean   | 210; 1,700 | 160; 1550 | 120; 1,400 | -       | -       |
| Aldan Shield, Proterozoic | 200; 1,700 | 145; 1,500 | 105; 1,400 | 70; 1,250 | -       |
| Anabar Shield, Proterozoic | 205; 1,700 | 145; 1,500 | 90; 1,300 | 70; 1,250 | -       |
Indian Shield, Proterozoic 210; 1,700 150; 1,500 100; 1,350 75; 1,300 -
Indian Shield, Archean 190; 1,650 - 100; 1,350 70; 1,250 -

Generalization of the data for several rifts in each region, including areas with relatively small erosional truncation, has enabled us to determine parameters of crustal sources. It can be concluded that parameters of magma chambers match predicted ones. No appreciable variation of those parameters versus age of the process could be registered either in the Precambrian or in the Phanerozoic (exactly as presumed by the APH).

4. Other continents

Outside Eurasia, studies of diverse endogenous conditions are largely limited.

Two data units can be identified in the most representative dataset for the Eastern African Rift: Strongly prevailing in one of them are concentrations of oxides which produces an estimated 100 km depth of the magma chamber and the temperature of 1,350°C. In the other, two bodies are identified with depths of the top portions amounting on the average to 115 km and 85 km. On the whole, the magma chambers’ parameters do not differ appreciably from those predicted.

Table 9. PT parameters of magma chambers in the mantle of Africa

| Region                                   | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|-----------------------------------------|---------|---------|---------|---------|---------|
| South Africa, Archean                  | 200; 1700 | 150; 1500 | 95; 1350 | -       | -       |
| South Africa, Archean, Rift            | 215; 1700 | 155; 1550 | 100; 1350 | -       | -       |
| Namibia, Archean, Proterozoic          | 180; 1600 | -       | 80; 1300 | 65; 1250 | -       |
| Egypt, Proterozoic                     | -       | -       | -       | 65; 1250 | -       |
| South Africa, Kimberlite               | 215; 1700 | 140; 1500 | -       | -       | -       |
| Marocco, Kameroon, Ghana, Riphean Rift | -       | -       | 90; 1300 | 60; 1200 | 30; 1150 |
| Marocco, Cimmerian Rift               | -       | 145; 1500 | 95; 1350 | 55; 1200 | 30; 1150 |
| Karroo                                 | 185; 1650 | 150; 1500 | 100; 1350 | -       | -       |
| Algeria, Alpides                       | -       | -       | -       | 40; 1150 | -       |
| Eastern Africa, Alpine Rift            | 185; 1650 | 145; 1500 | 95; 1350 | 55; 1200 | 20; 1150 |
| Nigeria, Alpine Rift                   | -       | -       | -       | 70; 1250 | -       |

The publications we used do not comprise enough data to characterize the Paleozoic geosynclinal process in North America. Meso-Cenozoic geosynclines, as well as Precambrian structures and rifts are described in greater detail.

Table 10. PT parameters of magma chambers in the mantle of North America

| Region                                   | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|-----------------------------------------|---------|---------|---------|---------|---------|
| Canadian Shield, Archean                | 210; 1700 | 150; 1500 | 105; 1400 | -       | -       |
| Canadian Shield, Proterozoic            | 185; 1650 | 140; 1500 | 95; 1350 | 60; 1200 | -       |
| Greenland, Proterozoic                  | -       | 170; 1600 | 85; 1300 | 65; 1250 | 15; 1100 |
| Appalacchians, Caledonides              | -       | -       | 95; 1350 | 60; 1200 | 35; 1150 |
| Newfoundland, Caledonides               | -       | -       | 105; 1400 | 70; 1250 | 35; 1150 |
| Alaska, Alpides                         | 230; 1750 | 150; 1500 | 100; 1350 | 55; 1200 | -       |
| Aleutians, Alpides                      | -       | -       | 105; 1400 | 55; 1200 | -       |
| Central Cordilleras, Alpides            | -       | -       | 80; 1300 | 50; 1200 | -       |
| Cascades, Alpides                       | -       | -       | 90; 1300 | -       | -       |
| Antilles Arc, Alpides                   | -       | 120; 1450 | 90; 1300 | 50; 1200 | -       |

9
On the whole, the available information (we are talking about representability of the analyses, rather than their quantity) is insufficient for offering a detailed picture of a continent with such an intricate geological history. Within the frameworks of a global overview, however, the obtained results are good enough since they are not at variance with those predicted.

Approximately the same applies to results on South America. Despite the predominance of information on the Andes in the dataset, andesites in them are poorly represented (isolated analyses). Information on Precambrian rocks in the Brazilian and Guiana shields is also scarce. Yet, all the parameters of the magma chambers are in fairly good conformity with predicted ones. Consequently, the goal of the overview has been met.

In Australia (including Tasmania) and on adjacent island arcs, a sufficient number of analyses have been considered to characterize the continent’s major tectonic regions. Certainly, not all levels of magma chambers in the mantle could be taken into account, but all the results fall within the predicted limits.

On the territory of Antarctica, the type of endogenous conditions does not always render itself to identification. That is why the rocks there were grouped exclusively in terms of their absolute age and territory. It has to be pointed out that in results obtained for Antarctica (with the exception of a small dataset on processes of Alpine age) one can commonly encounter a situation in which the third level of magma chambers shows up at the depths of 80 to 100 km or 90 km, and those results are equally well substantiated.

5. Data collation

Figures 5 and 6 show cumulative distributions of temperatures and depths for magma chambers in oceans and continents.

Figure 5. Histograms of distribution of temperatures and depths of magma chambers in the mantle of oceans (A) and continents (B).

Deviations from mean H and T values within groups characterizing magma chambers for each of the studied regions (in which there were sufficient numbers of determinations) do not differ from those presented above for several datasets on oceans and continents.

It would be wrong to assert that the obtained magnitudes of variations can be viewed as reliably established errors introduced by the measurement technique and besides, parameters of magma chambers must be somewhat dissimilar for different regions not just due to calculation errors. In reality, however, in the majority of cases the difference between the depths of neighboring magma

| Region                  | Depths (km) | Temperatures (°C) |
|-------------------------|-------------|-------------------|
| Rocky Mountains, Cimmerides | 205; 1,700 | 140; 1,500        |
| California, Cimmerides  | -           | 155; 1,550        |
| Mexico, Alpine Rift     | 200; 1,700  | 130; 1,450        |
| Great Basin, Alpine Rift| -           | -                 |
chambers is several times greater than 14 km based on detected variations. In other words, we are talking about separate bodies.

![Figure 6. Histograms of distribution of temperatures and depths of magma chambers in the mantle of the best studied areas of continents and oceans.](image)

Differentiation of magma chambers by levels becomes somewhat more distinct, the lows become deeper, but the depth range between 50 and 100 km is not as free from magma chambers at intermediate depths as is the case between 100 and 150 km or 150 and 200 km.

This might be due to the effect of both factors mentioned above: 1) submergence of the chamber’s top portion during the cooling of the material at the uppermost level and 2) melting of the basic eclogitized crustal blocks that sank into the mantle.

It is convenient to analyze the first situation on an example of Eastern Kamchatka – figure 7. According to the APH, after the completion in that region of the geosynclinal process proper, recent active processes resulted in the transfer of some of the material from the primary asthenosphere into the crust with a replacement of that material by a relatively cool eclogitized crustal substance. Over time, it underwent melting in the asthenosphere or sank below it, the temperature in the partial-melting layer dropped, and its top portion in a number of areas of the region plunged to a depth greater than 50 km, at which it used to lie prior to the onset of active processes. A velocity model of the region’s mantle was matched against the seismic wave velocity distribution at the solidus temperature of common mantle rocks and eclogites. This suggests that the concentration of eclogites is small and that they only reduced the solidus temperature but did not cause any increase in seismic wave velocities. The top of the asthenosphere occurs at depths of about 50-80 km. Incidentally, errors of determination of velocities and temperatures do not rule out a different pattern of distribution of partial-melting zones to an extent that the asthenosphere may have undergone a split into two segments with the top portions lying at the depths of about 40 km and 80-100 km. According to results of a petrological analysis of rocks, the melting foci from which Kamchatka’s young lavas spilled onto the surface are situated in the depth range from 70±10 to 140 ±20 km. The depth range characterized by high electrical conductivity in the mantle of Eastern Kamchatka (viewed as an integral region) varies from 70 to 110 km. The depth of the top portion of the melting focus, as established on the basis of aluminum and magnesium oxides in young volcanic rocks, varies within quite a wide range (figure 7). However, they reflect actual variations in depth of the asthenospheric surface depleted to various degrees by the process of recent active processes.
Figure 7. Partial melting zone in the mantle beneath Eastern Kamchatka.
1 – Boundaries of the high electrical-conductivity layer; 2–4 – Top portion of the contemporary asthenosphere based on velocity models for the south of the peninsula (2), center (3), north (4); estimated depths of the top portions of magma chambers according to aluminum and magnesium oxide concentrations in young rocks of Eastern Kamchatka (5).

The Curie temperature (Tc) of titanomagnetites in young rocks of Eastern Kamchatka enables us to trace magma sources in the crust (at 20–25 km) and in the subcrustal mantle (60 km).

Figure 8. P-wave velocities at the upper levels of the mantle beneath oil- and gas-bearing zones affected by recent active processes in Northern Eurasia.
1 and 2 – Velocity distribution at solidus temperatures of: 1 – peridotite, 2 -- with a small admixture of eclogite, 3 – mean velocity values at various depths and deviations from those values.

The above example does not unequivocally show the involvement of eclogites in the processes at the depths of 50-100 km. In all likelihood, the eclogites may have sunk to greater depths and are producing a positive velocity anomaly precisely there. In order to identify it at the depth of 50-100 km, it would be necessary to use much more information. Certainly, the times of the onset of events in zones of recent active processes in different regions do not coincide. Small variations are quite possible, in some cases resulting in the process reaching a stage shown for Kamchatka, whereas in others high-velocity eclogitized blocks only sank to the subcrustal part of the mantle. It is precisely the “velocity diversity” pattern that prevented us from identifying a discontinuity at the depth of about 50 km on the basis of velocity models for Northern Eurasia. If the entire information for zones of contemporary active processes on this territory is pooled together, one can observe quite a telling picture (figure 8). Despite the probability of substantial heating of the mantle’s subcrustal portion (in many hypothetical zones of recent active processes in Northern Eurasia, the heat flow has hardly been studied at all and the very existence of such zones was established proceeding from less reliable criteria, largely oil and gas presence), high Vp values, not infrequently higher than on platforms, are also quite common there. This can be accounted for by a considerable concentration of eclogitized blocks. In cases when they have undergone partial melting, the velocity decreases to values testifying to a small extent of partial melting.

When eclogite is present in large amounts and partial melting is relatively small, graph 2 in figure 8 shifts to the right.

In zones in question, small foci of partial melting may occur at different depths. It is, however, virtually impossible to verify their conformity with estimated depths. Kamchatka alone was included in the aforementioned compilation for regions with young magmatism.

The results of the study show coincidence (or similarity) between depths and temperatures of the major magma chambers in the mantle beneath oceans and continents. In terms of the advection-polymorphism hypothesis (APH), this is the only possible pattern. The point is that the maximum depth (200-250 km) from which mantle magmas can be transported to the surface or to the subsurface is restricted by the change in the sign of density contrast between the liquid and solid phases, the composition being the same. At such depths (unlike at shallower ones), the composition of melts is commonly close to the composition of rocks.
Acknowledgment: The authors wish to express special thanks to Mrs. Rita Schneider for translating this paper from Russian.

Additional information on the subject of the lecture and the bibliography in V.V. Gordienko THERMAL PROCESSES, GEODINAMICS, MINERAL DEPOSITS. 2017. https://ivangord2000.wixsite.com/tectonos