Available online at www.sciencedirect.com

ScienceDirect

Procedia Earth and Planetary Science 15 (2015) 585 – 589

Procedia
Earth and Planetary Science

World Multidisciplinary Earth Sciences Symposium, WMESS 2015

Petrological Geodynamic Model for the Evolution of the Crystalline Basement of the Eastern Russian Plate

Sitdikova Lyalya[a]*, Izotov Victor[a], Sidorova Elena[a], Khristoforova Darya[a]

[a]*Kazan federal university, Institute of Geology and Petroleum Technologies, Kremlyovskaya st., 4/5, 420008 Kazan, Russia*

Abstract

The east of the Russian plate is a typical platform area of Earth's crust. Geological, geophysical and seismic studies show active geodynamic processes within the region. Due to these active geodynamic processes, sub-horizontal tension is formed in the crystalline basement rocks. This leads to sub-horizontal displacements – "disruption" of large blocks of rocks which are associated with the occurrence of decompressed zones destruction.

Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.

Keywords: crystalline basement; Tatar arch; geodynamics; stage; destruction zone.

1. Introduction

The study of the crystalline basement of the Eastern Russian Plate has been conducted for over 50 years. The high degree of drilling of the crystalline basement is unique for the East European platform. Representations of material composition and age of rocks were based on a geophysical survey and core study of wells penetrating the basement on different depths. The study of the crystalline basement of the Eastern Russian Plate was performed by Lapinskaya T.S et al. by geophysical survey, geological structure of deep horizons, analysis of structural and tectonic position of the basement and surrounding aulacogen depressions from geodynamic position (The crystalline basement, 1996).

The active study of deep structures of Earth's crust by modern methods and ultra-deep drilling showed a heterogeneous structure of the crystalline basement of the Eastern Russian Plate, previously considered as inert geological formation.

* Corresponding author. Tel.: Tel.:+8-843-238-84-71; fax: +8-843-238-84-71.
E-mail address: sitdikova8432@mail.ru

Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.
doi:10.1016/j.proeps.2015.08.107

2. Geological overview

The east of the Russian plate is a typical platform area, within which the system of arched elevations is allocated: the North-Tatar and the South-Tatar arch (Lapinskaya and Bogdanova, 1976). Previously, it was believed that the crystalline basement of the Russian plate was an inert geological formation. Currently, based on geological, geophysical and seismological studies, we can conclude that there are active geodynamic processes within the basement. As a consequence of active geodynamic processes in the region, vertical and sub-horizontal stresses were formed in the crystalline basement (Sitdikova and Izotov, 1999). This led to sub-horizontal displacements – "disruption" of large blocks of rocks which are associated with occurrence of specific decompressed zones or zones of destruction which play an important role in the dynamics of the crystalline basement of the region (Sitdikova and Izotov, 2003).

3. Results and discussions

The formation of destruction zones in the Eastern Russian plate is associated with the general course of evolution of the region (Sitdikova and Izotov, 2006). According to geodynamic, mineralogical and petrological studies of deep and ultra-deep drilling and analysis of seismic profiles, it was established that the substance of the crystalline basement of the Tatar arch has undergone a complex evolution. There are the following stages of geodynamic development in the studied region.

3.1. Initial (nuclear) stage (Katarchean period)

In the initial (nuclear) stage of transformations and formation of primary rock protocrust was formed (Figure 1). It was composed of poorly differentiated substances close to ultrabasic composition. This crust had a high mobility and underwent high temperature metamorphism. The protocrust had been completely modified and is currently preserved only in the form of individual relics represented by bodies and lenses of ultramafite rocks in the basement (Bogdanova et al, 2010). Relics of such composition are determined according to deep drilling in formations of different age and different metamorphic modification of the basement.

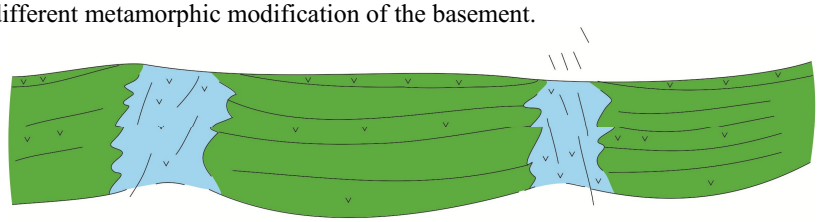

Fig. 1. The primary, weakly differentiated protocrust.

3.2. The stage of the early differentiation (Archean period)

There was an active developing of sialic crust by products of internal mantle differentiation (Figure 2). This period of geotectonic development in the region is associated with the proto-geosyncline stage. There were active tectonic movements and as a result, primary protocrust underwent high temperature and high pressure changes. Such changes led to a sharp differentiation of primary proto-substance. In the Archean period, there was an active increase of sialic crust by products of internal mantle differentiation. Formations of this period are also preserved as relics in areas of relatively calm orogeny in the southern and south-western periphery of the Tatar arch. They are represented by large highly differentiated mafite blocks (primary mafite complexes).

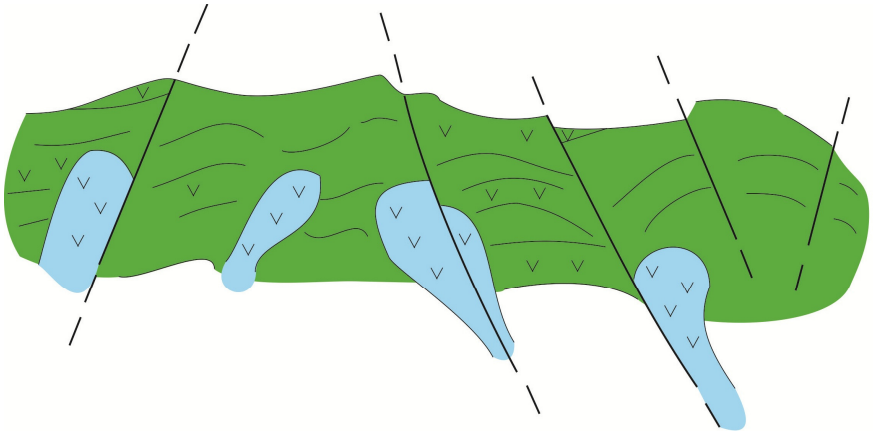

Fig. 2. Early differentiation of the primary protocrust.

3.3. Stage of the late differentiation and granitisation (Late Archean, Proterozoic periods)

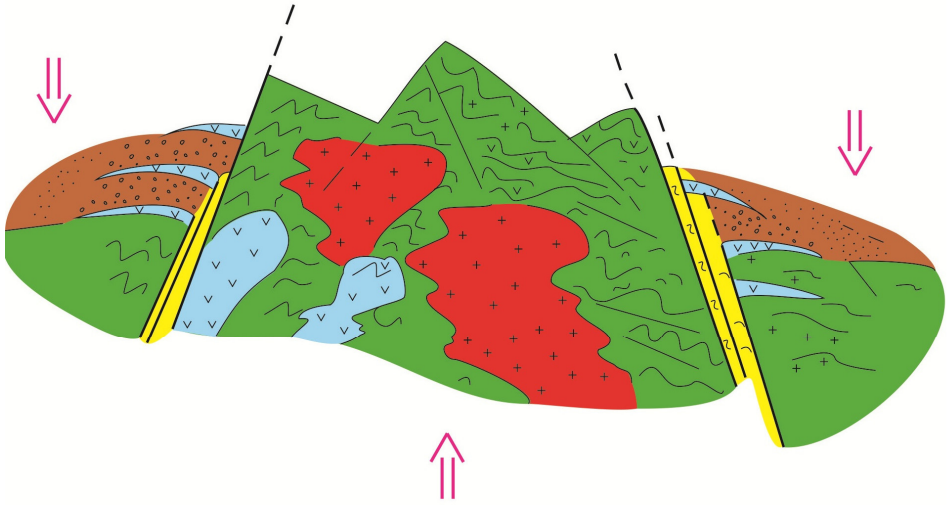

Fig. 3. Late differentiation and granitization of the protocrust. The initiation of regional faults. Starting of the large arched structures and aulacogens isolation. Development of tangential stresses.

After the formation of primary sialic crust within the Tatar arch, there was a period of active metamorphic modification. It took place under conditions of granulite facies of regional metamorphism (Bibikova et al, 2008). This stage is characterized by the formation of vast fields of granulite-gneiss complexes. It should be noted that this stage of formation underwent complex geodynamic conditions and high temperature gradients. According to paleo-temperature studies, the formation of granulite-gneiss complexes of this stage took place in heterogeneous thermal field. The occurrence of thermal fields (Khristoforova and Khristoforov, 2006) is connected with active processes of heat and mass transfer in deep sub-crustal horizons. Indicated processes led to further differentiation of a substance and laid the basics of the laminar-flake structure for both Tatar arches and their surroundings.

4. The stage of consolidated basement development

Further geodynamic evolution of the studied part of the Russian plate went through conditions of existing rigid base. Mainly, this period of Proterozoic and post-Proterozoic age is characterized by tectonic processes – disrupted dislocations, transition from linear-folded, flake-thrust structures into fault-block structures.

At the beginning of the Late Proterozoic, a system of faults occured in the extension mode, emphasizing the previous material and tectonic heterogeneity. In the most active zones, rift structures were laid – Sernovodksy-Abdulinsky, Kaltasinsky, Kirovsky-Kazhimsky aulacogens consisting of Riphean-Vendian sedimentary deposits (Figure 4). Thick strata of Riphean-Vendian deposits led to a deflection of the bed, accompanied by its crushing and intense basic magmatism. A series of sub-vertical and steeply dipping dikes are presented by rocks of gabbro-diabase formations. Mineralogical and petrographic studies show that gabbro-diabase formations are especially numerous in the eastern part of the Tatar arch and adjacent areas bordering the Preduralsky deflection. The intensity of magmatic activity was mixed: it was amplified and damped periodically, and this process continued until the Middle Devonian time.

As a result of the described processes, the structure of the South-Tatar arch was sandwiched between the Vyatsky-Kamsky and Kazan-Kirovsky aulacogen depressions accompanied by the formation of numerous fault zones. Frontal faults of arch-aulacogen were repeatedly rejuvenated, as evidenced by Riphean magmatism. According to geophysical data, these faults fell towards aulacogen depressions. During the lowering of the central parts of aulacogen along with flat dipping faults, strong tangential stresses in the basement strata were periodically developed. These stresses led to the development of the horizontal displacement of large granulite-gneiss plates in central parts of the arch. Sub-horizontal “disruption” zones were formed between separate plates of differential metamorphic substrate. Sub-horizontal zones of the basement destruction occurred and localized in them, which could be considered as decompression zones (Sitdikova, 2005). They were recorded in both geophysical data and petro-structural core studies of deep wells penetrated deep horizons of the basement.

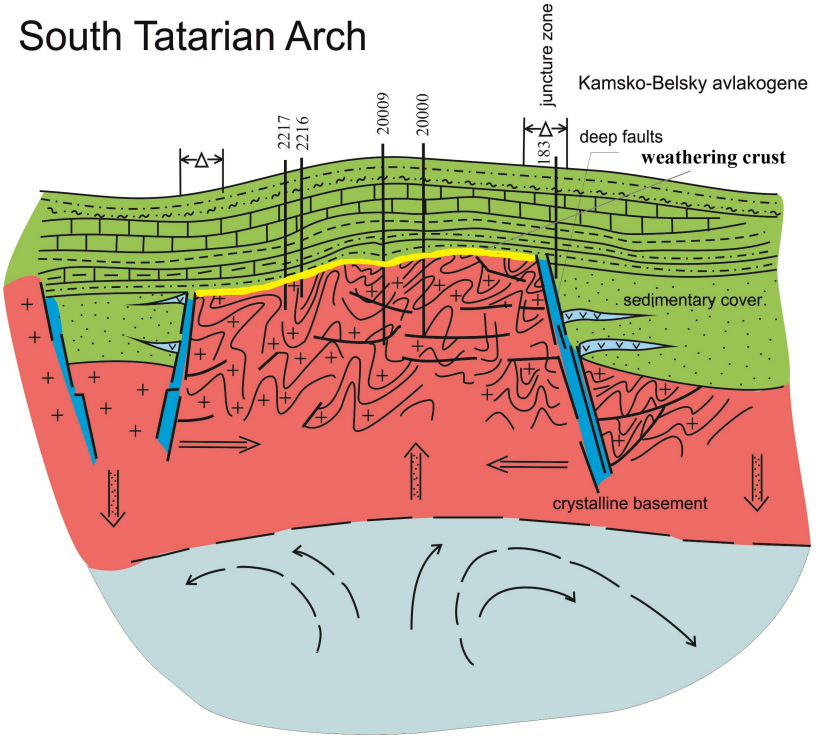

Fig. 4. Modern geodynamic scheme of the development of the basement of the Tatar arch. The formation of the later basement’s destruction zones was a result of geodynamic activation of tangential stresses.

The duration of the continental interval during which the basement rocks were subjected to weathering was different for individual parts of the Tatar arch. Profiles of weathering crust were formed, which were later covered by more juvenile sedimentary formations (Figure 4). Depending on the age of sedimentary rocks overlying the basement, there are pre-Riphean, pre-Vendian, pre-Eifelian, and pre-Middle Devonian weathering crusts (Lapinskaya and Zhuravlev, 1967; Sitdikov, 1968). Their thickness depends on the relief of the basement during the Paleozoic transgression of marine basins and ranges from several tens of meters in depressions to meters in elevations. They can be divided into areal and linear-fractural types that are associated with deep fault zones by morphological properties.

In the following eras of the Caledonian, Hercynian and Alpine tectogenesis, periodic renovation and rejuvenating of the destruction zones occurred. Periodically stresses and stress reliefs followed, expressed in the formation of destruction zones of compression and decompression type.

5. Conclusions

The formation of destruction zones in the Eastern Russian plate is associated with the general course of the platform formation. Currently, the destruction zones of the basement are the leading elements determining tectonic activity of the region. Considering the low total density of these zones, they could be considered as potential reservoirs for hydrocarbon-gaseous phases from the basement, the presence of which is confirmed by both petrographic research and experimental observations.

References

1. Bibikova, E.V., Larionova, A.N., Fedotova, A.A., Fugzan, M.M., Bogdanova, S.V., Kirnozova, T.I., Postnikov, A.V., Popova, L.P., 2008. New data on the age of the Early Archean granitoids of the Volga-Ural segment of the East European Craton. Reports of the Academy of Sciences, 419 (2): 1-5 (in russian).
2. Bogdanova, S.V., De Waele, B., Bibikova, E.V., Belousova, E.A., Postnikov, A.V., Fedotova, A.A., Popova, L.P., 2010. Volgo-Uralia: the first U-Pb, Lu-Hf and Sm-Nd isotopic evidence of preserved Paleoarchean crust. American Journal of Science, 310: 1345-1383.
3. Khristoforova, N.N., Khristoforov, A.V., 2006. Fluid migration and location of fractured layers in the crystalline basement by temperature logging in the Volga Region, Russia. Journal of Geochemical Exploration, 89: 187-190.
4. Lapinskaya, T.A., Bogdanova, S.V., 1976. The main features of the geological structure and the most important metamorphic and magmatic complexes of the Precambrian basement of the Volga-Ural oil and gas area. Geology, Petrology of crystalline formations of the East European platform, Nedra, Moscow, 106 p (in russian).
5. Lapinskaya, T.A., Zhuravlev, E.G., 1967. Buried weathering crust of basement of the Volga-Ural gas and oil presence province and its geological significance. Moscow, 174 p (in russian).
6. Sitdikov, B.S., 1968. Petrography and structure of the crystalline basement of the Tatar ASSR. Kazan, 436 p (in russian).
7. Sitdikova, L.M., 2005. Destruction zone of the crystalline basement Tatar arch. Kazan, 146 p (in russian).
8. Sitdikova, L.M., Izotov, V.G., 1999. Destruction zones of the crystalline basement as potential hydrocarbon reservoirs at great depths. Georesources, 1: 28-34 (in russian).
9. Sitdikova, L.M., Izotov, V.G., 2003. Geodynamic conditions of the formation of destruction type reservoirs. Georesources, 4: 17-22.
10. Sitdikova, L.M., Izotov, V.G., 2006. Formation of hydrocarbon reservoirs in the deep Earth`s crust. Journal of Geochemical Exploration, 89: 373-375.
11. The crystalline basement of Tatarstan and the problems of its oil potential, 1996. Kazan, 487 p (in russian).