

The Origin of the West Siberian Sedimentary Basin without Strong Crustal Stretching: An Analysis of Superdeep Drilling Data

Academician E. V. Artyushkov^{a,*} and P. A. Chekhovich^{a,b}

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Abstract—The mechanism of the formation of large sedimentary basins on the continents is among the main problems in geodynamics. The formation of such structures far from convergent plate boundaries is most often explained by intense stretching of the lithospheric layer (rifting). This should be followed by a large and prolonged crustal subsidence due to cooling of the stretched lithosphere. A characteristic feature of the post-rift subsidence is a decrease in its rate in time by several times over a hundred million years. Rifting in the West Siberian Basin was associated with the formation of Permian–Triassic graben-rifts. The subsequent (post-rift) subsidence is considered by many researchers as a cause of the formation of a thick layer of Mesozoic and Cenozoic sediments in the basin. Over the 86 Ma that passed from the beginning of the Middle Triassic to the end of the Middle Jurassic, the rate of post-rift subsidence should have decreased by about a factor of three. In fact, the opposite trend developed. Judging by the data of the Tyumen (SG-6) and En-Yakhin (SG-7) superdeep wells drilled in the northern part of the basin, the rate of crustal subsidence increased several times during this period of time. Such a sharp difference between the expected post-rift subsidence and the actual subsidence of the crust indicates that lithospheric stretching was not the main subsidence mechanism, and it could support only a small part of the subsidence. Under such circumstances, the main cause of the subsidence would have to be contraction of rocks in the Earth’s crust due to prograde metamorphism.

Keywords: crustal subsidence, deep-seated metamorphism, rock contraction in the lower crust, crustal stretching, West Siberian Basin, superdeep boreholes, rifting

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INTRODUCTION

One of the main types of structures of the continental crust are large and deep sedimentary basins. The nature of their formation is of great interest from both the fundamental and applied points of view. A number of studies have been devoted to this problem, and a number of different mechanisms have been proposed to explain crustal subsidence.

Kilometer-scale subsidence of the Earth’s crust in the areas located far from the boundaries between lithospheric plates can be caused by two main mechanisms, i.e., stretching of the lithospheric layer (see, e.g., [17, 19]) or contraction of rocks within it (see, e.g., [1, 3]). After the publication of work [17], the vast majority of researchers began to explain the formation of deep sedimentary basins by strong crustal stretching (rifting). It is often assumed that the stretching covers the entire lithospheric layer (see, e.g., [19]).

The crystalline basement of most of the deep sedimentary basins contains normal faults, which indicates that crust subsidence occurred under the conditions of crustal stretching. Hence, it is often concluded that the stretching was also a cause of the crustal subsidence. The depth of the structure formed by stretching, however, is closely related to its intensity. To form a sedimentary basin several kilometers deep, the lithosphere should have been extended by 10–15% (see below and [1]). Such stretching is inevitably accompanied by significant deformations in the crystalline basement of basins, which can easily be detected by seismic profiling.

According to classical models (see, e.g., [19]), another characteristic feature of crustal subsidence caused by strong crustal stretching is the continuing downward motion after termination of the initial stretching phase. This post-rifting subsidence is caused by the establishment of the new temperature distribution in the stretched lithosphere. The maximum rate of post-rift subsidence is reached during the end of stretching. Subsequently, the subsidence gradually slows down, and its rate decreases several times over 50–100 Ma. Such slowdown of crustal subsidence after its stretching (rifting) can be detected using geological data, provided there are deep boreholes

^a Institute of Physics of the Earth,
Russian Academy of Sciences, Moscow, Russia

^b Moscow State University, Moscow, Russia

*e-mail: arty-evgenij@yandex.ru

penetrating the whole section of the sedimentary cover and the underlying riftogenic volcanic strata. The deep drilling data has not been regarded from this point of view.

Sedimentary basins formed by crustal stretching can be reliably identified on the basis of two features—intense stretching in the basement and subsidence slowing in time. The basins formed in the inner parts of plates far from their boundaries bear no signs of stretching, and therefore, large and long-term crustal subsidence here can be explained only by rock contraction in the lithospheric layer [1]. Prograde metamorphism catalyzed by mantle fluids entering the crust has been proposed as its possible cause ([1, 3], etc.). This mechanism could have been put into motion by metamorphic reactions accelerated by mantle fluids penetrating the crust, as was proposed by D.S. Korzhinskii.

The structure of the sedimentary cover and basement has been studied in detail in many deep basins using deep seismic surveys. This makes it possible to estimate the amount of crustal stretching as the sum of horizontal gaps in the basement surface from each of the normal faults. Analysis of the structure of a number of sedimentary basins 10–20 km deep has shown that the actual basement extension was a few percentage points, and it provided only a small part (~1–2 km) of the crustal subsidence. Such a picture is characteristic, in particular, of the North Barents, North Chukchi, North Caspian, and South Caspian basins [2]. The absence of significant crustal stretching is also observed in numerous other deep sedimentary basins (see, e.g., [1]). This indicates that large subsidence caused by prograde metamorphism at various crustal levels is quite widespread.

RELATIONSHIP BETWEEN FORMATION OF A SEDIMENTARY BASIN AND RIFTING

The purpose of this review is to establish the processes that led to the formation of the West Siberian basin with an area of ~3.5 million km². Most researchers attribute its formation to the strong stretching of the Earth's crust and the entire lithospheric layer ([6, 13, 15] and others). This point of view is also reflected in university courses on regional geology and geodynamics. It can be summarized as follows: *the main cause of the formation of the large Epipaleozoic sedimentary basin in Western Siberia is intracontinental rifting*. Based on the available dating performed on various components of basaltic rocks (see, e.g., [11, 20]), it is believed that the main phase of crustal and lithospheric stretching can be compared with a rather narrow time interval near the Permian–Triassic boundary. At this time, systems of graben–rifts were formed in Western Siberia and traps erupted in the Siberian Craton.

As was noted earlier, the crustal stretching associated with the formation of Permian–Triassic graben–rifts could provide only a small part of the subsidence observed in the West Siberian basin [1]. It was suggested, therefore, that this basin could have been formed mainly due to densification (contraction) of rocks in the Earth's crust as a result of prograde metamorphism [1]. At that time, however, there was insufficient evidence to verify this point of view. To date, the basin has been covered by a network of deep seismic profiles (see, e.g., [7, 8]). A number of deep and ultra-deep wells penetrating the thick Mesozoic–Cenozoic sedimentary cover have also been drilled ([9, 10], etc.). All this allowed us to approach the discussion of the mechanism of formation of the West Siberian sedimentary basin at a new level. Below, we consider data from two superdeep wells, SG-6 (Tyumen) and SG-7 (Yen-Yakha), drilled in the area of the Nadym–Pur interfluvium and adjacent areas in the northern part of Western Siberia [10].

Both wells reached the last (shallowest) lava eruptions, indicating previous crustal stretching, at depths of more than 6.5 km (Lower Triassic). As was mentioned above, one of the signs of strong crustal stretching is the slowing subsidence during the post-rift stage. Over a time of about 70 Ma, the rate of such subsidence should decrease several times. It is easy to check whether such a slowing of crustal subsidence actually happened using the drilling data from wells SG-6 and SG-7. If such a slowdown did not occur, it would indicate that the main part of the subsidence was caused by some other mechanism.

CRUSTAL STRETCHING AT THE PERMIAN–TRIASSIC BOUNDARY

The West Siberian Basin (Fig. 1) is underlain by the crust of predominantly Hercynian and Caledonian age and is the largest sedimentary basin in the world. Its northern extension is a deep shelf depression of the Kara Sea. The vast Precambrian Siberian Platform adjoins the basin in the east. At the Permian–Triassic boundary, it was the site of huge trap eruptions [20], the total thickness of which reaches 6 km. In the same epoch, trap eruptions on a somewhat smaller scale occurred in Western Siberia [5, 11].

Basalt eruptions along the opening fractures indicate that the crust of Western Siberia was subjected to stretching in the Triassic. Most researchers have considered this phenomenon for decades as the main cause of the formation of the West Siberian sedimentary basin (see, e.g., [6, 14]). The branched system of Triassic graben–rifts bounded by faults (Fig. 1) discovered in West Siberia (see, e.g., [4, 6, 10, 12]) is considered as the main indication of crustal stretching in West Siberia. The largest of them, the 10–80 km wide Koltogor–Urengoi graben–rift, crosses Western Siberia, stretching from north to south over 1800 km. The Yamal graben branches from it in the northwesterly

direction. The Khudosei graben-rift is located in the eastern part of the platform. It is assumed that the paleorift grabens are bounded by normal faults up to 2 km high. Positive gravity anomalies are observed above the grabens due to the occurrences of high-density basalts. The grabens are also characterized by increased heat fluxes and magnetic anomalies stretched along the strike of the structures. The grabens are overlain by the Mesozoic–Cenozoic sedimentary cover up to 6–7 km thick or more.

CALCULATED AMOUNT OF STRETCHING REQUIRED TO FORM A SEDIMENTARY BASIN

Let us consider the simplest model of the Earth's crust as a layer with thickness h_c^0 and average density ρ_c , located at the initial stage near sea level. The temperature in the lithospheric layer increases linearly with depth, reaching values characteristic of the asthenosphere at the base of the lithosphere. Let us assume that the lithosphere together with the crust were stretched uniformly in depth by a factor of β , which led to the rise of isotherms while the heat flux through the surface increased by the same factor. After the stretching ceased, the lithosphere gradually cooled, and after several hundred million years, the former vertical equilibrium temperature distribution was restored. Cooling rocks in the lithosphere are contracted due to thermoelastic contraction, which leads to crustal subsidence and the formation of a depression. Under the conditions of isostatic equilibrium, the maximum thickness of sediments with density ρ_s , which hereafter fill the depression, equals

$$h_s = [(\rho_m - \rho_c)/(\rho_m - \rho_s)](1 - 1/\beta)h_c^0, \quad (1)$$

where $\rho_m = 3330 \text{ kg/m}^3$ is the density of the mantle. Knowing the sediment thickness h_s from Eq. (1), we can determine the stretching intensity β associated with the formation of the depression:

$$\beta = \{1 - [(\rho_m - \rho_s)/(\rho_m - \rho_c)](h_s/h_c^0)\}^{-1}. \quad (2)$$

The average thickness of the crust near sea level in most areas is $h_c^0 = 40 \text{ km}$, and its average density is $\rho_c = 2840 \text{ kg/m}^3$. In the absence of large masses of dense limestone, the average sediment density in the Mesozoic–Cenozoic sedimentary basin of Western Siberia can be estimated at $\rho_s = 2300 \text{ kg/m}^3$. Substituting these values into (1), (2), we obtain

$$h_s = 19(1 - 1/\beta)_{\text{km}}, \quad (3)$$

$$\beta = [1 - 0.053 \times (h_s)_{\text{km}}]^{-1}. \quad (4)$$

For the West Siberian sedimentary basin, the value of h_s can be estimated, e.g., from the data of two super-deep wells drilled in its northern part, the Tyumen well SG-6 (depth 7502 m) and the En-Yakha well SG-7

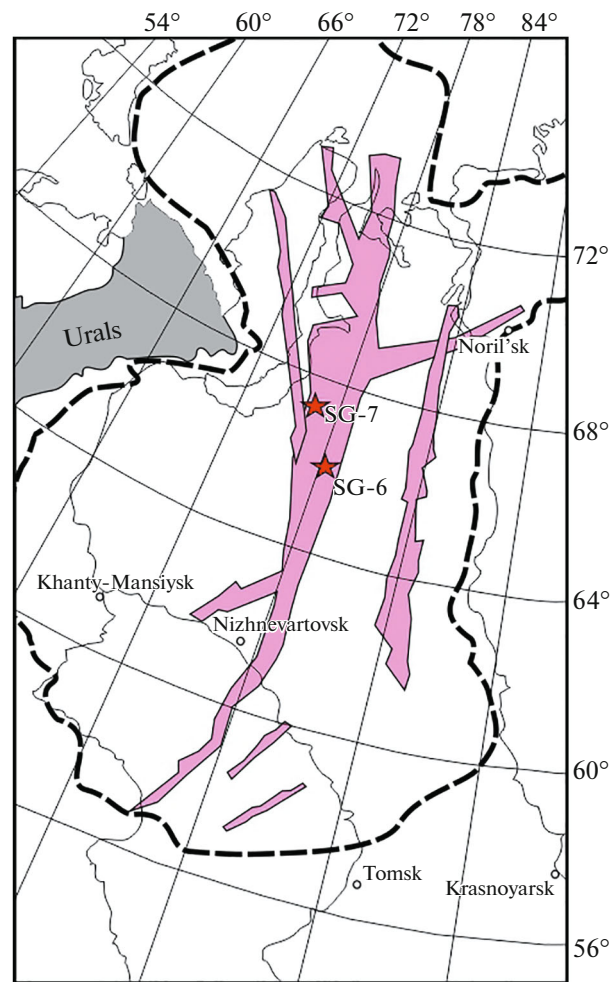


Fig. 1. System of rift structures (colored) in the Paleozoic folded basement of the West Siberian sedimentary basin (modified from [10]). The location of superdeep wells is shown with asterisks, and the boundaries of the sedimentary basin are shown with a dotted line.

(depth 8250 m) [9, 10]. The locations of the wells are shown in Fig. 1, while Fig. 2a shows the lower parts of the corresponding sections.

At a depth of more than 7 km, both boreholes entered the Upper Permian basalts. In the eastern part of the Nadym-Pur area (SG-6), basalt eruptions still continued in the Early Triassic, accumulating more than 800 m of basalts. About 200 m of basalts accumulated at the beginning of the Early Triassic in more western areas (SG-7). Thereafter, no intense eruptions occurred in the entire Nadym-Pur area and crustal subsidence developed predominantly under conditions of terrigenous sedimentation.

As follows from Fig. 2a, crustal stretching with eruptions of basaltic magmas stopped at the boundary of the Early and Middle Triassic in the area of the Tyumen well and at the beginning of the Early Triassic in the area of the En-Yakha well. Let us assume that the

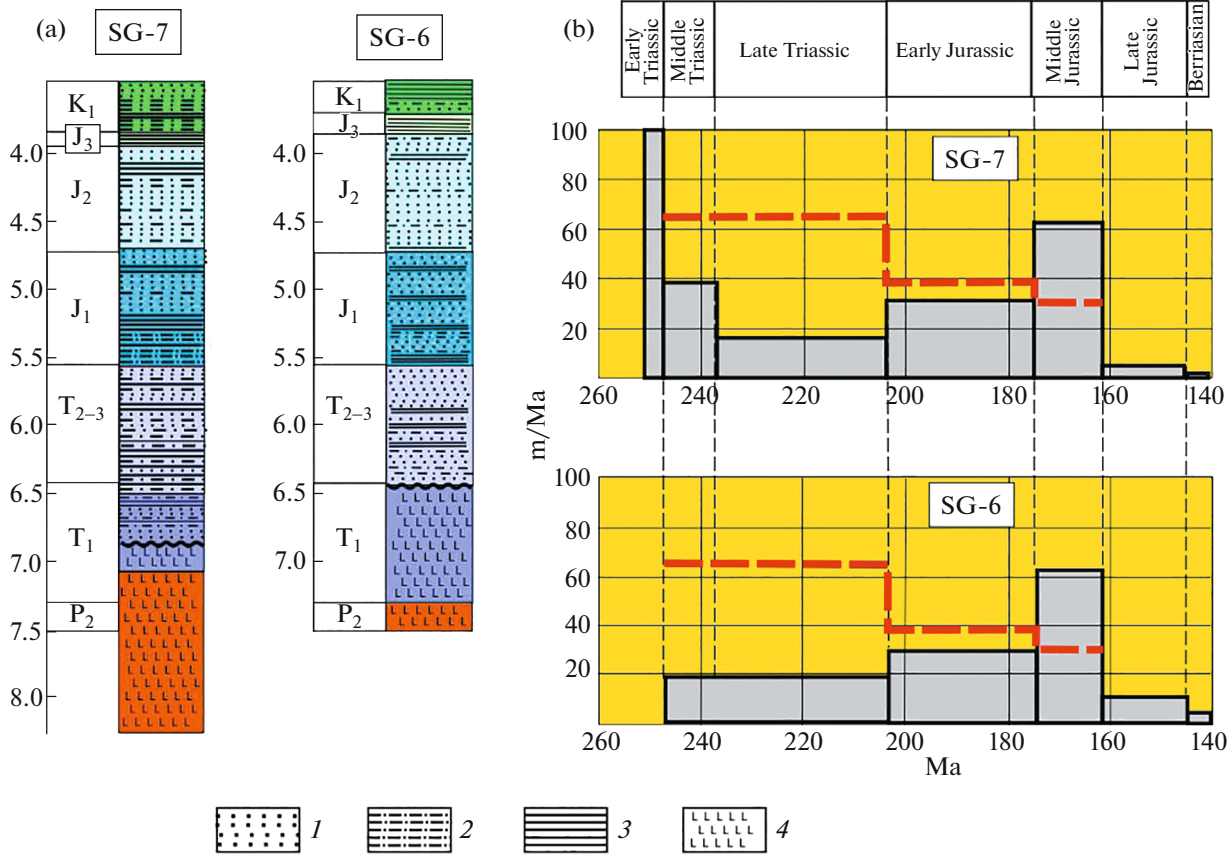


Fig. 2. Dynamics of post-rift sedimentation in the northern part of the West Siberian Basin. (a) Sections of Mesozoic sediments based on superdeep drilling data (modified from [10]); 1, sandstones, gravel conglomerates; 2, siltstones; 3, bituminous mudstones; 4, basalts. (b) Average sedimentation rates based on drilling data (gray bars of the diagram) and rates obtained from the theoretical model of post-rift subsidence due to crustal stretching (red dotted line; see also Fig. 3).

subsequent crustal subsidence was entirely due to its previous stretching. To estimate its intensity roughly, we can use the thickness of sediments accumulated above the indicated levels after the stretching was completed. This thickness in the Tyumen well is $h_s = 6.4$ km, and in the En-Yakha well, it is $h_s = 6.9$ km. Substituting these values into relation (4), we obtain

$$\beta = 1.51-1.58. \quad (5)$$

The relative crustal stretching $\varepsilon = \beta - 1 = 51-58\%$. Thus, if the crustal subsidence in the areas under consideration had a post-rift character, i.e., was associated with the preceding stretching, the crust would have to be extended at least by half, i.e., very significantly. The thickness of Mesozoic and Cenozoic strata in the Yarudei borehole on the western slope of the basin is 4.4 km [10]. Substituting $h_s = 4.4$ km into (2), we find $\beta = 1.30$, $\varepsilon = 30\%$, which also corresponds to rather intense stretching.

The stretching intensity in the vicinity of well SG-6 was estimated earlier [6], on the basis of data on the history of crustal subsidence. Model lithospheric stretching varied over depth. It was assumed that

strong stretching took place in several stages. The researchers concluded that the stretching resulted in a 1.7-fold thinning of the crust. Such high estimates of the β -factor, at first glance, are consistent with the data on significant thinning of the consolidated crust beneath the axial part of the basin in the northern part of Western Siberia [18].

Modern numerical capabilities allow crustal subsidence in a sedimentary basin to be described within the framework of many different models of lithospheric stretching. It is usually assumed, however, that crustal subsidence was entirely due to crustal stretching. According to Eq. (3), the magnitude of the sediment-loaded crustal subsidence h_s is closely related to the intensity of its stretching. Therefore, first of all, it is necessary to make sure that the observed crustal stretching was sufficient for its subsidence. Moreover, the post-rift subsidence of the stretched lithosphere follows a certain law [19], exponentially decaying in time. Consequently, it is also important if there was a significant slowing down of the crustal subsidence, as is characteristic of the post-rift subsidence of the cooling lithosphere. If any of these conditions is not met,

then a large contribution of lithospheric stretching to its formation is excluded.

THE EVOLUTION OF POST-RIFT SUBSIDENCE

The pure shear model [19] is usually used to describe the subsidence of the Earth's crust as a result of strong stretching of the lithospheric layer in large areas. It is assumed that the lithosphere temperature increased linearly with depth and that the Earth's surface is initially located at sea level. At time $t = 0$, the lithosphere is instantaneously stretched throughout the section. To maintain isostatic equilibrium, the stretched lithosphere experiences immediate syn-rift subsidence. Then, at $t > 0$, it develops gradual post-rift subsidence. This is caused by rock contraction in the course of gradual cooling of the thinned lithosphere as the temperature returns to its initial pattern.

In some regions of Western Siberia, thick volcanic sequences were accumulated as early as the Permian (see, e.g., [7, 8]). Large trap eruptions continued even at the beginning of the Triassic. Consequently, if there was an intensive syn-rift subsidence in Western Siberia, it did not occur in the form of a short pulse, but continued over a considerable time interval. The model in [19] is inapplicable to this epoch, especially since the history of the Paleozoic crustal subsidence remains unstudied. Post-rift subsidence was documented by drilling data, from SG-6 and SG-7 (Fig. 2), and from a number of other wells. Thus, the real crustal subsidence according to the data of superdeep wells in the Triassic and Jurassic can be compared on a qualitative level with the post-rift subsidence that would have developed after the completion of rapid stretching according to the pure shear model.

In the case where post-rift subsidence is compensated by sedimentation, over ≈ 100 Ma, the thickness of sediments deposited at time t is described with good accuracy by the relation [19]

$$h_s(t) = H[1 - \exp(-t/\tau)]. \quad (6)$$

The rate of crustal subsidence which is compensated by sedimentation,

$$v_s = dh_s/dt = (H/\tau)\exp(-t/\tau). \quad (7)$$

Here τ is the characteristic temperature recovery time in the lithospheric layer and H is the sediment thickness eventually reached in the basin. The τ value depends on the lithospheric thickness before stretching d and increases in proportion to its square d^2 . The lithospheric thickness assumed in [19] was $d = 125$ km, while the characteristic thermal relaxation time was found to be $\tau = 73$ Ma. The thickness of the lithosphere beneath Precambrian platforms is usually estimated as $d \sim 200$ km [16], and the thermal relaxation time may be $\tau \sim 200$ Ma. The sediments in Western Siberia are underlain by a crystalline basement of predominantly Caledonian and Hercynian age. At the

beginning of the Mesozoic, the thickness of the lithosphere must have been much lower than on the Precambrian platforms. Under such conditions, the above value $\tau = 73$ Ma deduced from [19] can be used as a first approximation for rough estimates.

THE SUBSIDENCE RATE BASED ON DATA FROM WELL SG-6

According to the data for borehole SG-6, the accumulation of significant volumes of volcanics stopped by the end of the Early Triassic. Therefore, it can be assumed that, at the turn of the Early and Middle Triassic, 247 Ma ago, crustal stretching had ended and post-rift subsidence began. Later vertical crustal movements inevitably manifested on the continents and caused by other mechanisms were superimposed upon it. Due to the latest crustal uplift that occurred in the Oligocene, Western Siberia became dry land. Under such conditions, it is impossible to determine accurately the sediment thickness H that would have been reached after the establishment of a new temperature distribution in the stretched lithosphere. For simple estimations, let us assume this value to be equal to the thickness of sediments accumulated in the area of the Tyumen superdeep well by the beginning of the latest uplift: $H = 6400$ m.

The curve of the sediment thickness build-up that would compensate for the post-rift crustal subsidence was calculated using Eq. (6) for a given value of H and the relaxation time $\tau = 73$ Ma, which is depicted in Fig. 3. The sediment-compensated subsidence rate curve (7), obtained for the same values of H and τ , is plotted in the same figure. According to (7), this rate decreases exponentially with time. It should be noted that the curves in Fig. 3 describe the post-rift crustal subsidence with good accuracy only for the time interval of ≈ 100 Ma. In the present work, however, we analyze crustal subsidence in well SG-6 over a shorter time interval of 86 Ma (from the beginning of the Middle Triassic to the end of the Middle Jurassic), which ensures sufficient accuracy.

The stratigraphic column of the SG-6 borehole section shown in Fig. 2a, in principle, allows the crustal subsidence curve to be constructed and compared with the typical post-rift subsidence curve. However, all we are interested in here is whether stretching could be considered the main cause of crustal subsidence in the area of well SG-6. To obtain an unambiguous answer, we can use the following simple and illustrative technique.

The thicknesses of the Lower and Middle Jurassic in borehole SG-6 (see Fig. 2a) are almost identical; they are only 10% less than the total thickness of the Middle and Late Triassic. The chronostratigraphic extent of these units, however, differs significantly (see Fig. 2b). The combined duration of the Middle and Late Triassic (45.8 Ma) is about 1.7 times that of the

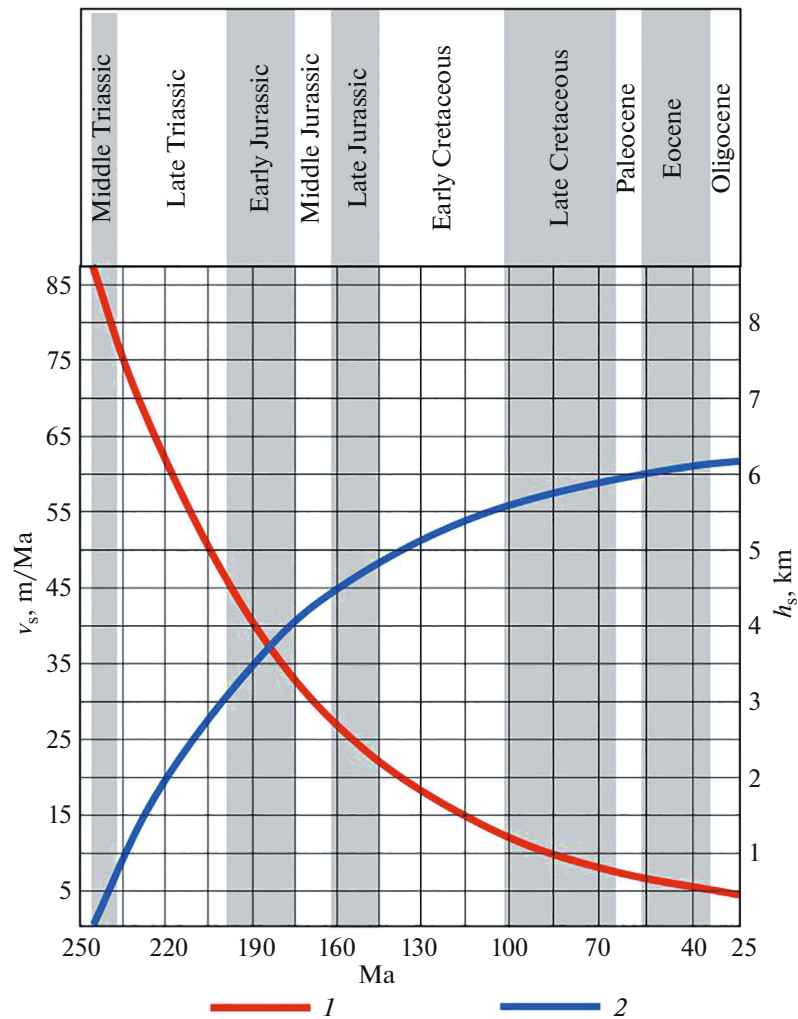


Fig. 3. Evolution of the post-rift crustal subsidence in Western Siberia after the completion of stretching at the turn of the Early and Middle Triassic. (1) Rate of subsidence compensated by sedimentation (m/Ma) and determined by Eq. (7); (2) thickness of sediments (km) that compensate for the subsidence developing according to Eq. (6).

Early Jurassic (26.7 Ma) and 3.5 times that of the Middle Jurassic (13.2 Ma), which in turn is twice as short as the Early Jurassic. Thus, as can be seen from Fig. 2a, while the sediment thicknesses of these units are close, the average sedimentation rates for them were very different (Fig. 2b). They are 19.7, 30, and 62.9 m/Ma for the Middle–Late Triassic, Early Jurassic, and Middle Jurassic, respectively. These data show that the average subsidence rate in the area of well SG-6 increased several times over the period of 86 Ma from the beginning of the Middle Triassic to the end of the Middle Jurassic.

The duration of this interval (86 Ma) exceeds the above-mentioned characteristic temperature recovery time in the lithosphere after its strong stretching (73 Ma according to [19]). In accordance with Eq. (7), the post-rift subsidence should have slowed down approximately three times by the end of the Middle Jurassic. Figure 3 shows the post-rift sediment accu-

mulation at time t after the end of stretching. From this curve, it is easy to determine how much sediment would have been deposited during each of the three intervals of time shown in Fig. 2b. Dividing the thickness of the sediments accumulated during the given interval by its duration, we find the average crustal subsidence rate during these time intervals (65.1, 39.2, and 29.7 m/Ma). The obtained values of the average subsidence rate are shown in Fig. 2b with a red line. It is easy to see that the average post-rift subsidence rate in the area of well SG-6 should have decreased several times over from the Middle Triassic to the Middle Jurassic. Actually, the crustal subsidence rate increased several times during the same time. Thus, the crustal subsidence in the area under consideration was mostly not related to crustal stretching but was caused by a different mechanism.

THE SUBSIDENCE RATE BASED ON DATA FROM WELL CG-7

The En-Yakha well SG-7 is located 160 km northwest of the Tyumen well. The Early and Middle Jurassic stratigraphic units in SG-7 are almost the same as in the Tyumen well. The average crustal subsidence rate in the well in the Middle Jurassic (~62 m/million years) was twice as high as in the Early Jurassic and three times higher than in the Late Triassic. The crustal subsidence rate in the SG-7 region should have decreased several times during the subsidence caused by the preceding rifting from the Late Triassic through the Middle Jurassic. Actually, the crustal subsidence accelerated several times. This indicates that the entire territory of the Nadym-Pur interfluvial area was in the Jurassic within a crustal block that was sinking under the action of a mechanism not related to stretching.

It should be noted that the early stage of subsidence in the area of borehole SG-7 was characterized by a significant slowdown. The accumulation of volcanics was completed 1–2 Ma after the beginning of the Triassic. After the subsequent 2–3 Ma, the thickness of sediments in the borehole was 280 m, which corresponds to a high average subsidence rate of ~90–140 m/Ma. During the 10 Ma-long period of the Middle Triassic, however, the average subsidence rate dropped to 38 m/Ma and later gradually increased again. These data may indicate that crustal subsidence occurred in the area of the En-Yakha well for ~10 Ma due to crustal stretching at the very beginning of the Triassic. In this case, however, the crustal stretching could ensure accumulation of no more than ~0.5 km of post-rift sediments. Other possible mechanisms of subsidence at this stage cannot be excluded either. One of them could be, e.g., contraction of small rock volumes in the lower crust due to prograde metamorphism catalyzed by the minor influx of fluids from the mantle [1, 3].

DISCUSSION

The mechanism of formation of large sedimentary basins on continents and continental margins is one of the main problems in geodynamics. The formation of basins located far from the boundaries of convergent plates is often explained by strong stretching of the lithospheric layer (see, e.g., [19]). There are, however, ideas about the formation of sedimentary basins as a result of rock contraction in the Earth's crust due to prograde metamorphism (see, e.g., [1, 3]). Understanding the mechanism of formation of large sedimentary basins is very important both from a fundamental point of view and for the hydrocarbon prospecting and exploration. The latter issue, however, remains debatable.

Most researchers associate the formation of the West Siberian sedimentary basin, the largest in the world, primarily with the stretching of the lithosphere

([6, 13, 15], etc.). It is assumed that the large crustal subsidence that occurred in the basin in the Mesozoic and Cenozoic time was caused by the preceding stretching of the lithospheric layer (rifting), which occurred at the end of the Permian and the beginning of the Triassic. A characteristic feature of the post-rift crustal subsidence is the gradual decrease in the subsidence rate (see, e.g., [19]). Therefore, the post-rift crustal subsidence should have slowed down several times from the beginning of the Middle Triassic to the end of the Middle Jurassic. The analysis of data from the Tyumen and En-Yakha superdeep wells drilled in the northern part of Western Siberia has shown, however, that crustal subsidence, instead, accelerated several times over that time.

Such a sharp discrepancy between the actual data and theoretical constructions indicates that lithospheric stretching could be responsible for only a small part of the crustal subsidence recorded by the borehole data. Therefore, stretching was not the main mechanism of crustal subsidence; the latter was probably caused by densification (contraction) of rocks in the bottom part of the lithosphere.

The subsidence mechanisms operating in other geodynamic settings (e.g., near plate boundaries) are not applicable to the West Siberian basin. In particular, the elastic bending of the lithospheric layer, which is believed to form the foreland basins, could not have functioned in West Siberia during the Mesozoic–Cenozoic, because no collisional processes were occurring in adjacent areas. Furthermore, the depocenter of the basin is located in its inner part, not at its boundaries. Crustal subsidence in intraplate regions can also be related to the impact of downward currents in the underlying mantle on the base of the lithosphere (the so-called dynamic topography). This model is inconsistent with the long history of formation of the West Siberian Basin, which lasted for more than two hundred million years within approximately the same boundaries. Downward currents in the mantle could not have persisted for such a long time beneath the basin, which, moreover, drifted as part of the Eurasian plate.

CONCLUSIONS

On the basis of the above analysis, it can be concluded that the only known mechanism of subsidence in Western Siberia in the absence of strong stretching may be the contraction of rocks in the crust caused by prograde metamorphism. The analysis of data from ultra-deep boreholes SG-6 and SG-7 carried out in this work indicates, strictly speaking, the absence of significant crustal stretching in the Mesozoic and Cenozoic only in the northernmost regions of Western Siberia, in the regions of Nadym-Pur and Pur-Taz. The applicability of the proposed mechanism to the entire West Siberian sedimentary basin requires, however, additional consideration and reinterpretation of a

large volume of available geological and geophysical materials. In particular, a number of high-precision seismogeological sections through the Mesozoic–Cenozoic sedimentary cover have recently been constructed for the northern part of Western Siberia and the Kara Sea (see, e.g., [7, 8]). Using that data, it would be possible to estimate reliably the magnitude of crustal stretching that preceded the formation of a huge sedimentary basin in the Mesozoic and Cenozoic. The processes in the Earth’s mantle that led to the formation of the West Siberian sedimentary basin without significant crustal stretching should also become the subject of further research.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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