Russian Geology and Geophysics © 2020, V.S. Sobolev IGM, Siberian Branch of the RAS
Vol. 61, No. 9, pp. 1028–1035, 2020 DOI:10.15372/RGG2019170 *Geologiya i Geofizika*

Regional Magnetostratigraphy of the Upper Cretaceous and the Cretaceous–Paleogene Boundary in Southern West Siberia as Applied to Complitation of the Cretaceous Magnetic-Polarity Scale

Z.N. Gnibidenko✉, O.B. Kuzmina, A.V. Levicheva

Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, Russia, 630090

Received 4 April 2019; received in revised form 9 October 2019; accepted 10 October 2019

Abstract—Magnetostratigraphic data from wells in southern West Siberia that strip the Upper Cretaceous and Cretaceous–Paleogene boundary strata in three areas (three wells in the Omsk Basin, two wells in the Bakchar Iron Basin, and two wells in the southern Kulunda Basin) are used to compile the respective regional magnetic-polarity scale. According to the available biostratigraphic constraints, the deposition spanned the period from Albian to Bartonian. The reported regional polarity scale is based on integrated paleomagnetic and biostratigraphic data from the seven wells and comprises four Upper Cretaceous zones of normal (NK_{1-2}(al-st) and NK_2mt) and reverse (RK_2km and RK_2mt) polarity corresponding to the C34, C33r, C31r, and C30n Chrons of the global magnetic polarity scale and four Paleogene zones of reverse polarity: R_1E_1zl, R_2E_1t, R_1E_2t-i(?), and R_1E_2l-b, with the first two correlating with the C26r and C25r Chrons. Some of the Upper Cretaceous magnetozones enclose thin intervals (microzones) of the opposite polarity. The regional Cretaceous–Paleogene magnetic-polarity scale of southern West Siberia reveals several deposition gaps from 6 to 28 Myr long. The magnetostratigraphic data can be used to determine deposition rates and can make reference for local, regional, and global correlations of geologic events given that polarity reversals are of global extent.

Keywords: paleomagnetism; magnetostratigraphy; geomagnetic polarity; magnetozone; Upper Cretaceous; Paleogene; southern West Siberia

INTRODUCTION

Compiling local and regional magnetostratigraphic columns for major geological provinces of the World is indispensable for creating the magnetic polarity scales of continents and the global polarity scale. The polarity scales record the evolution of the geomagnetic field and are useful to update regional stratigraphic records and to solve exploration problems. The paleomagnetic scales and correlation charts based on the distribution of natural remanent magnetization of rocks over the geological time are still incomplete in space and time. Namely, the available paleomagnetic data from Cretaceous sections of the West Siberian basin, one of World largest petroleum provinces, are limited to a few publications, while data from southern West Siberia are missing. In this respect, paleomagnetism of sediments deposited in the Upper Cretaceous and at the Cretaceous–Paleogene boundary in southern Siberia is of special theoretical and practical value.

The first paleomagnetic evidence from Cretaceous sediments in West Siberia was collected more than fifty years ago (Pospelova et al., 1967). It was from Valanginian and Hauterivian sediments in the Khatanga Basin (Boyarka River catchment); Valanginian sediments in the Anabar Bay; Neocomian sediments of the Ilek Formation in the Chulym-Yenisei Basin (Ilek Mt., Shestakovo and Kursko–Smolenskoe communities). The first reconnaissance studies showed that the rocks were suitable paleomagnetic objects. Pospelova et al. (1967) revealed alternating zones of normal and reverse polarity in the Valanginian strata. The Lower Cretaceous (Valanginian-Barremian) continental sediments of the Chulym-Yenisei basin (Ilek Formation) studied later (Pospelova and Larionova, 1971) in three natural outcrops (Ilek Mt. in the Chulym catchment; Shestakovo and Kursko-Smolenskoe communities in the Kiya and Serta catchments, respectively) showed normal polarity. Those early studies revealed the positions of paleomagnetic poles from average natural remanent magnetization of sediments in the three sampled outcrops, which represented the East Siberian Sea, as well as the paleolatitude of the study area at the time of deposition (Early Cretaceous).

Paleomagnetic data from the Upper Cretaceous strata and across the Cretaceous–Paleogene boundary in southern West Siberia provide additional constraints on the age of the sediments, the position and volume of deposition gaps, and on local and regional stratigraphic schemes.

We began systematic high-resolution paleomagnetic studies of Upper Cretaceous sediments in southern West Si-

✉Corresponding author.
E-mail address: GnibidenkoZN@ipgg.sbras.ru (Z.N. Gnibidenko)

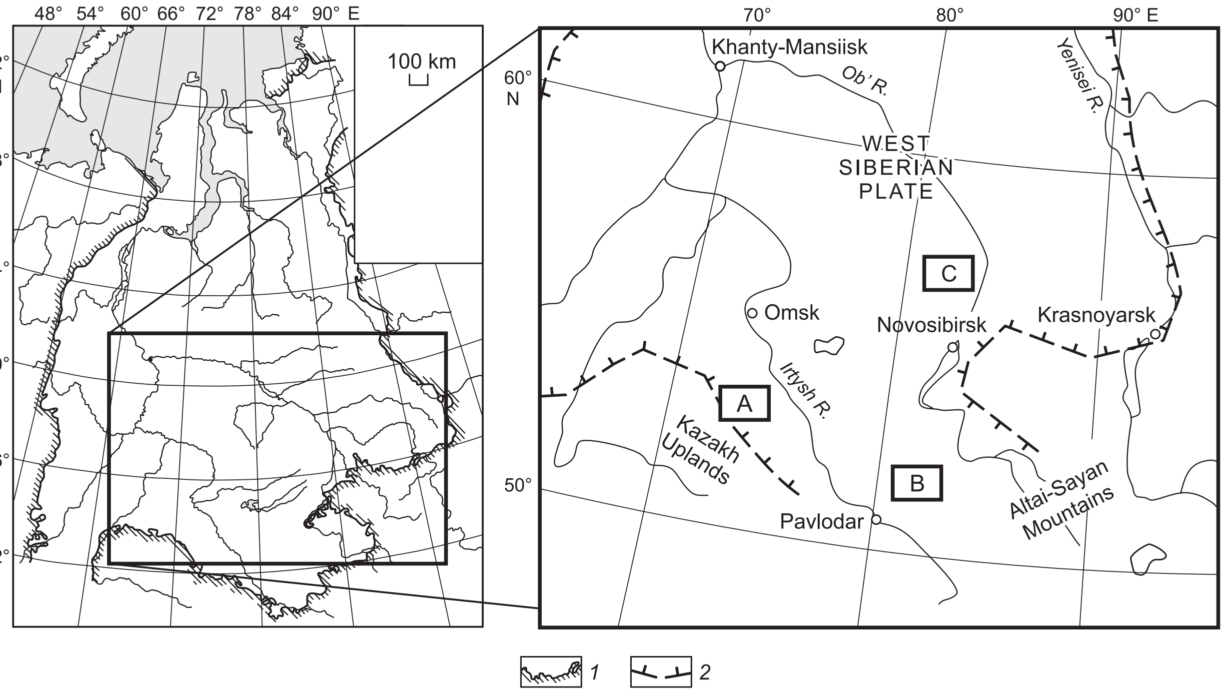

Fig. 1. Location map of wells in Upper Cretaceous and Cretaceous–Paleogene boundary strata in southern West Siberia. A, Omsk Basin (3 wells); B, southern Kulunda Basin (2 wells); C, Bakchar Iron Basin (2 wells). *1, 2*, limits of the West Siberian Plate.

beria in 2011. The results obtained since then include: magnetostratigraphic records of seven wells that stripped Upper Cretaceous and Cretaceous–Paleogene boundary sections in three areas (Fig. 1): Omsk (wells 8, 10, 2), Bakchar (wells S-114, S-124), and southern Kulunda (wells 23 and 19) basins; a correlation chart of the wells; a composite regional Upper Cretaceous and Cretaceous–Paleogene geomagnetic polarity scale as a fragment of the respective Cretaceous scale of West Siberia. All studies were based on integrated paleomagnetic, paleontological, geological, and stratigraphic data.

This publication is a synopsis of Upper Cretaceous–Paleogene paleomagnetic data collected for the eight years that elapsed since 2011, which will be used further to compile the geomagnetic polarity scale of the Cretaceous and then for the whole Mesozoic of the West Siberian Plate.

BIOSTRATIGRAPHY

Cretaceous and Paleogene marine and continental deposits are widespread in southern West Siberia. The Upper Cretaceous and Cretaceous–Paleogene boundary sections in wells from the Omsk, Bakchar, and southern Kulunda basins differ in completeness, facies, significance, and faunas. The Upper Cretaceous strata consist of the Pokur, Kuznetsovo, Ipatovo, Slavgorod, and Gankino formations in the Omsk and Bakchar basins, and Lenkovo and Sym formations in the southern Kulunda Basin. The Paleogene sediments comprise the Talitsa, Lulinvor (Omsk Basin), Yurki (Bakchar Basin), and Ostrovnoje (Kulunda Basin) formations.

The ***Upper Cretaceous*** sections are the most complete in the **Omsk Basin**.

The Pokur Formation is stripped at core depths of 593–408 m, 522–368.2 m, and 441.2–349 m in wells 8, 10, and 2, respectively, with the respective thicknesses 185 m, 153.8 m, and 92.2 m. The formation is composed mainly of continental facies deposited in the Albian, Cenomanian, and Turonian, with age constraints from spore and pollen and from dinocysts in the upper part (Lebedeva et al., 2013; Lebedeva and Kuzmina, 2018). The Pokur Formation rocks are mostly of normal magnetic polarity interrupted by two 2 m thick intervals of reverse polarity in all three wells (Gnibidenko et al., 2012, 2014) (Fig. 2).

The Pokur Formation is erosively overlain by the 7.6 to 28.0 m thick ***the Kuznetsovo Formation*** that contains Lower Turonian (wells 10 and 2), and Middle and Upper Turonian (wells 8, 10, and 2) dinocysts (Lebedeva et al., 2013; Lebedeva and Kuzmina, 2018). The Kuznetsovo Formation is of normal polarity in all three wells, and a 17 m thick interval of reverse polarity was found in well 8. The deposition occurred in a marine environment.

The Ipatovo Formation lies over the eroded surface of the Kuznetsovo Formation and varies in thickness from 10 to 40 m in the three wells 8, 10, and 2. Its Coniacian-Santonian age is constrained by dinocysts found in all three wells (Lebedeva et al., 2013; Lebedeva and Kuzmina, 2018). The formation was likewise deposited in a sea. The magnetic polarity is mainly normal in the three wells, with three intervals of reverse polarity, like in the Kuznetsovo and Pokur formations: two 2 m thick intervals in well 8 and one 3 m

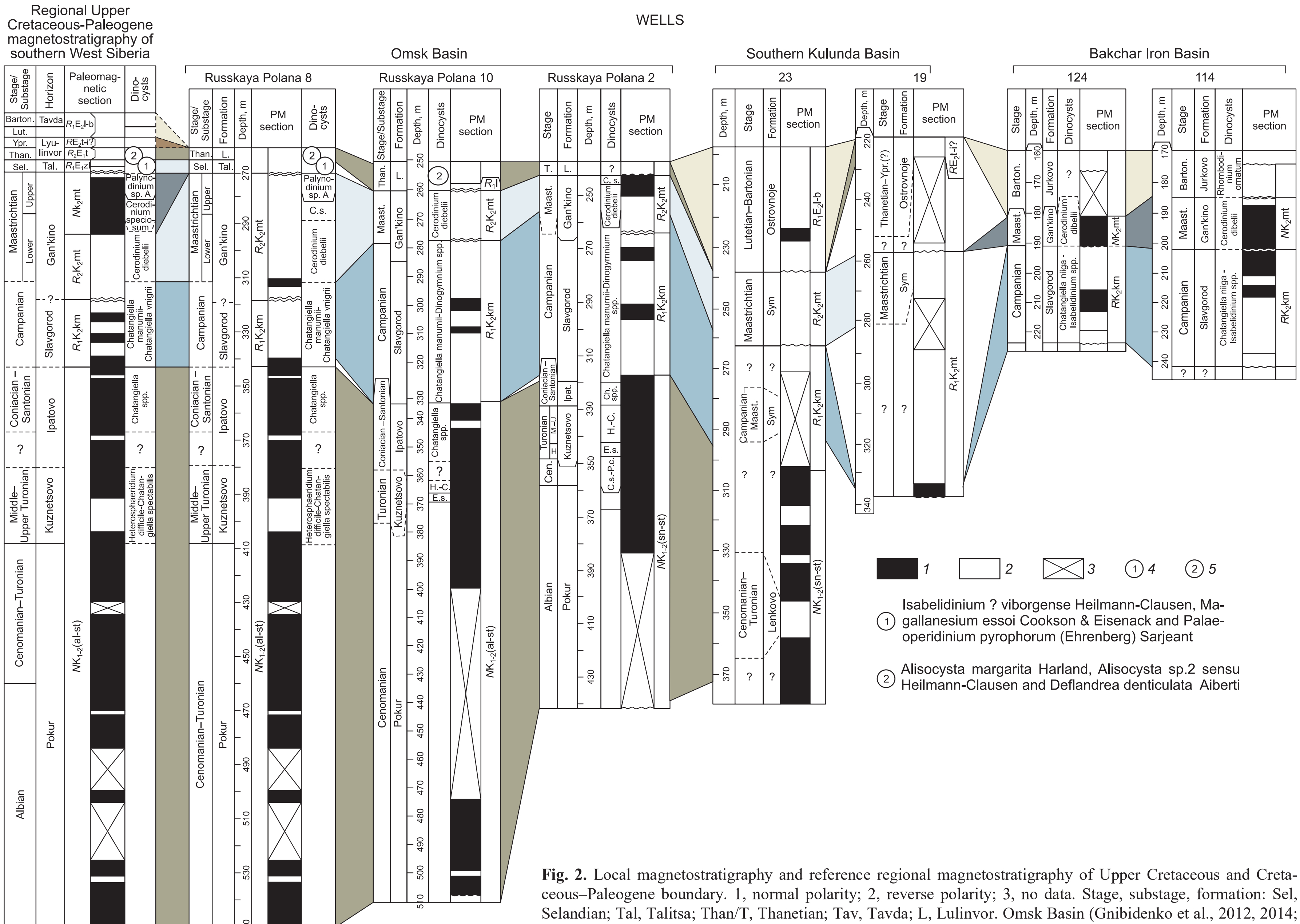

Fig. 2. Local magnetostratigraphy and reference regional magnetostratigraphy of Upper Cretaceous and Cretaceous–Paleogene boundary. 1, normal polarity; 2, reverse polarity; 3, no data. Stage, substage, formation: Sel, Selandian; Tal, Talitsa; Than/T, Thanetian; Tav, Tavda; L, Lulinvor. Omsk Basin (Gnibidenko et al., 2012, 2014; Lebedeva et al., 2013); Bakchar Basin (Gnibidenko et al., 2015; Lebedeva et al., 2017); southern Kulunda Basin (Gnibidenko et al., 2017; Lebedeva et al., 2019).

interval in well 10. The Pokur, Kuznetsovo, and Ipatovo formations, along with the lowermost Slavgorod Formation (Gnibidenko et al., 2012, 2014), jointly make up a single normal polarity magnetozone $N\mathrm{K}_{1\text{-}2}$(al-st) with five reverse polarity intervals (Fig. 2).

The Slavgorod Formation lying over the locally eroded Ipatovo Formation surface varies in thickness from 31.8 to 60 m and has a Campanian age (Lebedeva et al., 2013; Lebedeva and Kuzmina, 2018). Its basal rocks show normal polarity in wells 8 and 2 and make the uppermost and thinnest part of the $N\mathrm{K}_{1\text{-}2}$(al-st) magnetozone, while the greatest part of the formation in wells 8 and 2 and the entire volume in well 10 are of reverse polarity with two normal-polarity intervals in wells 10 and 4 (2 and 4 m thick, respectively) and one 5 m thick interval in well 2. Thus, most of the Slavgorod Formation belongs to the $R_1\mathrm{K}_2$km zone of reverse polarity (Gnibidenko et al., 2012, 2014) (Fig. 2). The formation was deposited in a sea basin.

The Gankino Formation lies erosively over the Slavgorod Formatio. and ranges in thickness from 17.8 to 38.2 m. It contains abundant fossils, including dinocysts, spores and pollen, as well as bivalves, ammonites, and gastropods, which place the deposition between Late Campanian and Late Maastrichtian time (Lebedeva et al., 2013; Lebedeva and Kuzmina, 2018). In wells 8, 10, and 2, the formation, with a single normal-polarity interval (2.5 m thick in well 8) belongs to another zone of reverse polarity: $R_2\mathrm{K}_2$mt (Gnibidenko et al., 2012, 2014). The sediments were deposited in marine conditions.

The Upper Cretaceous sections of iron-rich sediments in the **Bakchar Iron Basin** (wells S-114 and S-124) are less complete than those in the Omsk Basin, and are reduced to the Slavgorod and Gankino formations. The stratigraphic division and dating are based on spore-pollen data from Upper Cretaceous and Paleogene sediments collected by Lebedeva and Kuzmina, respectively (Gnibidenko et al., 2015; Lebedeva et al., 2017). ***The Slavgorod Formation*** is the thickest, spanning core depths 224–192 m (32 m) and 224–188 m (36 m) in wells S-114 and S-124, respectively. The formation has a Campanian age constrained by dinocysts (identified by Lebedeva) and corresponds to reverse polarity zone $R_1\mathrm{K}_2$km interrupted by normal-polarity intervals which are 2.7 and 6.4 m thick in well S-114 and 10 m thick in well S-124 (Gnibidenko et al., 2015). ***The Gankino Formation*** is 6 and 6.5 m thick in the two wells where it occurs at core depths of 190–184 m (S-114) and 190–183.5 m (S-124). The sediments contain Maastrichtian dinocysts (Gnibidenko et al., 2015; Lebedeva et al., 2017) and belong to normal-polarity zone $N\mathrm{K}_2$mt (Fig. 2). The formation was deposited in a sea and is overlain by Paleogene strata with a large gap.

Southern Kulunda Basin. The Upper Cretaceous continental clay, alternated clay/sand, and sand of the Lenkovo and Sym formations were studied in wells 23 and 19. The Upper Cretaceous deposits of the area were previously reduced to the Gankino Formation according to the stratigraphic division suggested by Rusanov (Gnibidenko et al., 2017). However, new biostratigraphic data (Lebedeva et al., 2019) distinguish the continental Lenkovo and Sym formations, which are stratigraphic equivalents of the marine Kuznetsovo, Slavgorod, and Gankino formations in the southern West Siberian Plain (Omsk and Bakchar basins and other areas) and have palynologically constrained Senomanian-Turonian and Campanian-Maastrichtian ages, respectively (Lebedeva et al., 2019).

The Lenkovo Formation rocks (core depths 375–297 m) show normal polarity with three reverse-polarity intervals: 14.3 and 7 m thick in well 23 and 5 m thick in well 19. The reverse polarity intervals within the Sym Formation occur at depths 297–230 m in well 23 and at 340–258 m in well 19 (Fig. 2).

Cretaceous–Paleogene boundary. Omsk Basin. ***The Talitsa Formation*** lies, with a gap, over Upper Cretaceous sediments and appears only in well 8 (Omsk Basin). It is composed of light gray clay silt and fine sand and contains Middle Selandian dinocyst assemblages (Fig. 2) (Iakovleva et al., 2012). The sediments were deposited in a relatively shallow sea. In wells 10 and 2, the Gankino Formation is overlain with a gap by the ***lower Lulinvor Subformation*** of alternated green quartz-glauconite sandstone, gray and light gray clay, light gray sand, and glauconite silty marl (Iakovleva et al., 2012; Lebedeva and Kuzmina, 2018). The deposits contain stratigraphically significant Upper Paleocene dinocyst species. The geomagnetic polarity is reversed (Fig. 2). The deposition was in a shallow sea.

Bakchar Basin. Biostratigraphic data reveal no Paleocene sediments in wells S-114 and S-124 in the Bakchar Basin. In our previous work (Gnibidenko et al., 2015), the Paleocene age of the Lulinvor Formation in wells S-114 and S-124 was inferred from geological and stratigraphic evidence but had no biostratigraphic constraints. According to recent biostratigraphic data from well S-114 (Lebedeva et al., 2017), the Gankino Formation is overlain, after a large gap, by ***the Yurki Formation*** sandstone, a facies equivalent of the Tavda Formation, which was deposited during a regression of the Tavda Sea (Gurari et al., 2001). The Yurki Formation. Formation contains a dinocyst assemblage with *Rhombodinium ornatum (Kisselevia ornata)* and a spore-pollen assemblage with *Castanopsis pseudocingulum, Castanea crenataeformis,* and *Nyssa crassa* indicating a Middle Eocene (Bartonian) age (Lebedeva et al., 2017). The Yurki deposition was in a brackish shallow-marine environment, during a reverse polarity span (Gnibidenko et al., 2015) (Fig. 2).

Southern Kulunda Basin. Wells in the southern Kulunda basin likewise lack Paleocene sediments. Paleogene sediments from wells 19 and 23 were attributed to the marine Talitsa and Lulinvor formations in our previous study (Gnibidenko et al., 2017) before new biostratigraphic data (Lebedeva et al., 2019) have distinguished the continental Ostrovnoje Formation (Fig. 2). The formation was mapped within the Kulunda and Fore-Altai lithofacies areas of the West Siberian Plain as a facies equivalent of the Talitsa, Lulinvor, and Tavda formations (Gurari et al., 2001). The Upper Cretaceous strata lie under sediments that contain a spore-pollen assemblage of a presumably early-middle Eocene age with *Tricolporopollenites pseudocingulum, Castanopsis pseudocingulum,* and *Castanea crenataeformis* in well 19 and under those with middle Eocene spore-pollen assemblages in well 23: Lutetian-Bartonian *Tricolporopollenites cingulum, Castanopsis pseudocingulum, Castanea crenataeformis* and Bartonian *Tricolporopollenites cingulum, Tricolpopollenites liblarensis,* and *Quercus gracilis* lying over the Sym Formation. (Lebedeva et al., 2018; 2019). The pollen species found in wells 19 and 23 correspond to deposition in a continental conditions and bear no signatures of a marine environment. Thus, the Cretaceous strata in the southern Kulunda Basin lie under the continental **Ostrovnoje Formation** (Gurari et al., 2001). The wells strip only a part of this formation corresponding to the lower (?)-middle Eocene (Lutetian-Bartonian), which is composed of brownish-gray clay, gray, dark-gray, and bluish-gray silty or sometimes muddy clay, with disseminated carbonaceous matter and brownish to gray fine and very fine quartz-feldspar sands. The Ostrovnoje Formation in wells 23 and 19 shows reverse polarity with a single 3.5 m thick normal-polarity interval in well 23 (Fig. 2).

METHODS

The methods of sampling and paleomagnetic analysis were described in detail in several recent publications (Gnibidenko et al., 2012, 2015, 2017). Altogether, we have studied 1600 m of core from seven wells in three local sedimentary basins of southern West Siberia: 2416 cube-shaped slabs from 756 oriented (top-bottom) samples. The determined parameters included magnetic susceptibility (χ) and natural remanent magnetization or remanence (NRM), Koenigsberger ratio (Qn=Jn/Ji); the samples were subject to stepwise thermal and alternated field (AF) demagnetization and analysis of NRM components. Magnetic minerals were identified by thermomagnetic analysis (TMA) and differential thermomagnetic analysis (DTMA).

RESULTS

Data on rock magnetism and paleomagnetism from the seven wells in three local basins of southern West Siberia show that the Upper Cretaceous and Paleogene sediments from the region are magnetically heterogeneous. Magnetic susceptibility and natural remanent magnetization are the lowest in clay, silt, and sand from wells 23, 19 in the southern Kulunda Basin ($1.0–33\times10^{-5}$ SI and *n*0.1 to 8.5 mA/m, respectively) and the highest in clay, silt, and sand from wells S-114 and S-124 in the Bakchar Basin (25 to 120×10^{-5} SI and 1.5 to 55 mA/m, respectively; on average 70×10^{-5} SI units and 30 mA/m, respectively). The respective values for samples from three wells in the Omsk Basin (8, 10 and 2) are intermediate between those of the Bakchar and southern Kulunda basins.

Anisotropy of magnetic susceptibility estimated using the simplified χ_{max}/χ_{min} ratio of Nagata (1965) is low (χ_{max}/χ_{min} = 1–1.04, or less than 4%) and almost invariable in different rock types.

Remanence and its preservation depend on the properties of magnetic minerals, carriers of paleomagnetic information. In this respect, paleomagnetism is closely associated with rock magnetism, which provides evidence on compositions and percentages of magnetic minerals, sizes of magnetic grains, and magnetic rigidity, with implications for paleomagnetic stability and genesis of magnetic minerals and for their alteration. Thus, one can gain information recorded at the time of deposition or during a known dated event. The ratios Qn < 1 indicate the origin of magnetization, in our case it is the orientation (detrital) origin of NRM (Molostovskii and Khramov, 1997). This inference is consistent with the clay, silt, mudstone, and sandstone lithology of sediments. Note that depth-dependent variations in magnetic parameters have no correlation with polarity reversals, i.e., the characteristic remanent magnetization (ChRM) component does not depend on percentage, composition, and structure of magnetic grains.

The χ dependence of NRM is linear in wells S-114 and S-124 of the Bakchar Basin and in well 19 in the Kulunda Basin, where they depend thus on the amount of magnetic particles (Gnibidenko et al., 2015, 2017). However, the distribution is cloud-like in well 23 where the χ_{max}/χ_{min} ratio is 0.5–0.1.

The rocks of the three basins share much similarity in the assemblages and origin of magnetic minerals: mainly magnetite, hematite, and titanomagnetite of clastic origin and also iron hydroxides (goethite and hydrogoethite) in samples from the Bakchar Basin (Gnibidenko et al., 2015, 2017).

The NRM components were analyzed by stepwise thermal and AF demagnetization (Gnibidenko et al., 2012, 2015, 2017). The revealed ChRM component was used to compile local Upper Cretaceous and Paleogene paleomagnetic sections of the seven wells in three facies zones; additional use of integrated data allowed creating the respective geomagnetic polarity scales.

Correlation of the Upper Cretaceous and Paleogene sections from the Omsk–Larya, Tomsk and Kulunda facies zones (3 wells in the Omsk Basin, 2 wells in the Bakchar Basin, and 2 wells in the southern Kulunda Basin, respectively) allowed us to reconstruct the regional Cretaceous and Cretaceous–Paleogene magnetostratigraphy of southern West Siberia which encompasses equivalents of biostratigraphic units from Albian to Bartonian (Fig. 2). The regional polarity scale illustrates the magnetic division of the Upper Albian, Cenomanian, Turonian, Coniacian, Santonian, Campanian, and Maastrichtian stages of the Cretaceous and the Selandian, Thanetian, Lutetian, and Bartonian stages of the Paleogene. The reliability of paleomagnetic data depends on NRM components and on the possibility to pick the primary component, as well as on the correlation of the paleomagnetic record in the documented wells with the global magnetic polarity time scale (Ogg et al., 2016) and with coeval sections from other regions worldwide.

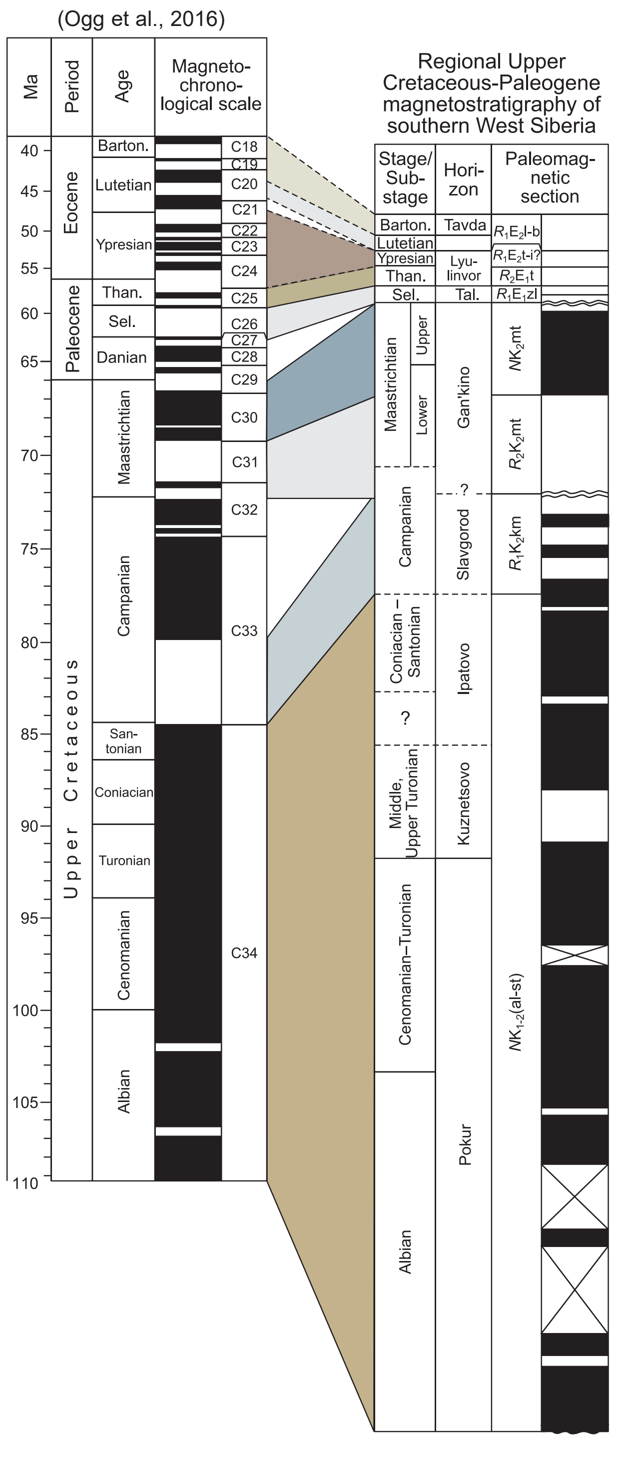

Fig. 3. Regional Upper Cretaceous and Cretaceous–Paleogene magnetostratigraphy of southern West Siberia and the Global Magnetic Polarity Time Scale (Ogg et al., 2016). Legend same as in Fig. 2.

The obtained regional polarity scale of southern West Siberia comprises four Upper Cretaceous magnetozones, including two zones of normal polarity (NK_{1-2}(al-st) and NK_2mt) and two zones of reverse polarity (R_1K_2km and R_2K_2mt), and four Paleogene reverse-polarity zones: R_1E_1zl, R_2E_1t, R_1E_2t-i?, and R_1E_2l-b. Each magnetozone of the Upper Cretaceous encloses opposite polarity intervals. The paleomagnetic record was correlated with the regional stratigraphy using fauna data (Iakovleva et al., 2012; Lebedeva et al., 2017, 2018, 2019; Lebedeva and Kuzmina, 2018), i.e., the position and sequence of magnetozones have biostratigraphic controls.

The regional Upper Cretaceous and Cretaceous–Paleogene geomagnetic polarity scale of southern West Siberia (Figs. 2, 3) was correlated with the global polarity time scale of Ogg et al. (2016). The earliest large magnetozone NK_{1-2} (al-st) spans a period from the Upper Albian through the Campanian. Three upper zones R_1K_2km, R_2K_2mt, and N_2K_2mt cover the range from the Lower Campanian to the Maastrichtian. Zones NK_{1-2}(al-st), R_1K_2km, R_2K_2mt, and N_2K_2mt (a part of the Upper Maastrichtian) are equated, respectively, to Chrons C34, C33r, C31r, and C30n of the global magnetic-polarity time scale (Ogg et al., 2016). Two Paleogene zones of reverse polarity R_1E_1zl (Paleocene) and R_2E_1t may correlate, respectively, with C26r and C25r Chrons (or their fragments), but two others (R_1E_2t-i? and R_1E_2l-b) have no equivalents in the global scale identified as yet. Note that the long normal-polarity zone NK_{1-2}(al-st), which spans Upper Albian through Campanian sediments, corresponds to a superzone, while zones R_1K_2km, R_2K_2mt and N_2K_2mt can be ranked as orthozones.

Paleomagnetic and biostratigraphic data used jointly reveal a gap between the Campanian and Maastrichtian strata (Slavgorod and Gankino formations) since the regional magnetostratigraphic record misses equivalents of Chrons C33n and C32 (Ogg et al., 2016) that span about 7 Myr. The gap between the Mesozoic and Cenozoic strata (Upper Cretaceous–Maastrichtian to Paleogene) is from 6 Myr in the west of the region (missing Chrons C30–C27 in the Omsk Basin) to ~26–28 Myr in the east (missing Chrons C29-C19 and C30-C19 in the Bakchar and southern Kulunda basins, respectively).

The normal superzone NK_{1-2}(al-st) in the regional magnetic-polarity scale comprises five thin intervals of reverse polarity or R-microzones (Figs. 2, 3): in the Early and Upper Albian and Middle-Upper Turonian sediments, and in the lower (Ipatovo Formation) and upper Coniacian-Santonian strata (undifferentiated). The presence of reverse polarity zones in the Turonian and Santonian contradicts the classical view of uniform polarity in Cretaceous superchron C34, but agrees to a certain extent with data on coeval deposits from the East Caucasus, West Kopetdag, and Tuarkyr areas (Fomin and Eremin, 1993; Fomin and Molostovskii, 2001; Fomin, 2003; Guzhikov et al., 2003, 2007), as well as from the Volga region (Guzhikova et al., 2019). The reverse polarity microzones may be of high correlation value for the region. The obtained data for the Campanian-Maastrichtian are in line with the available knowledge of the Late Cretaceous geomagnetic setting and can be correlated with the Campanian-Maastrichtian magnetostratigraphic records from the Russian Plate (Guzhikov et al., 2017; Guzhikova and Ben'yamovskii, 2018; Guzhikov et al., 2020) and Northern Mediterranean (Gardin et al., 2012) areas.

CONCLUSIONS

The integrated paleomagnetic, paleontological, and stratigraphic studies of well cores from three basins in southern West Siberia (wells 8, 10, 2 in the Omsk Basin; wells S-114, S-124 in the Bakchar Basin; and wells 23 and 19 in the southern Kulunda Basin) were used to compile the regional magnetic-polarity scale of the Upper Cretaceous and Cretaceous–Paleogene boundary strata. The magnetostratigraphic record includes four zones of normal (NK$_{1-2}$(al-st) and NK$_2$ mt) and reverse (RK$_2$km and RK$_2$mt) polarity in the Upper Cretaceous, which are equated to the magnetic Chrons C34, C33r, C31r, and C30n of the global scale (Ogg et al., 2016), and four reverse polarity zones in the Paleogene: R_1E$_1$zl, R_2E$_1$t, R_1E$_2$t-i? and R_1E$_2$l-b; the first two are presumable equivalents of Chrons C26r and C25r. Some Upper Cretaceous magnetozones include microzones of the opposite polarity.

The regional Upper Cretaceous-Paleogene magnetostratigraphic record of southern West Siberia reveals deposition gaps between the Campanian and the Maastrichtian (Slavgoord and Gankino formations) and between the Mesozoic and the Cenozoic (Upper Cretaceous–Maastrichtian and Paleogene). The gaps are, respectively, 7 Myr and from 6 to 28 Myr long (6 Myr in the Omsk Basin in the west of the region and ~26–28 Myr in the east, in the Bakchar and southern Kulunda basins). The compiled regional polarity scale can be used to estimate deposition rates and to correlate local and regional geologic events to the global time scale.

The study was supported by the Russian Science Foundation: Projects No. 0331-2019-0004 "Paleontology, stratigraphy, biogeography of the boreal and adjacent paleobasins and complex substantiation of the improvement of regional stratigraphic schemes of the Mesozoic and Cenozoic of Siberia", and 0331-2019-0012 "Lithospheric Processes in Siberia: Evidence from Monitoring of Magnetic and Thermal Fields, Seismology, and Laboratory Experiments".

REFERENCES

Fomin, V.A., 2003. Upper Cretaceous magnetostratigraphy of the East Caucasus, West Kopetdag, and Tuarkyr Areas [in Russian]. PhD Thesis, Saratov.

Fomin, V.A., Eremin, V.N., 1993. Upper Cretaceous magnetostratigraphy of the southern USSR territory, in: Kuleva, G.V., Ochev, V.G. (Eds.), Problems of Paleozoic, Mesozoic, and Cenozoic Stratigraphy [in Russian]. Saratov University, Saratov, pp. 134–142.

Fomin, V.A., Molostovskii, E.A., 2001. Cenomanian magnetostratigraphy of West Turkmenistan. Bull. MOIP, Ser. Geol. 7 (4), 62–70.

Gardin, S., Galbrun, B., Thibault, N., Coccioni, R., Silva, I.P., 2012. Bio-magnetochronology for the upper Campanian–Maastrichtian from the Gubbio area, Italy: new results from the Contessa Highway and Bottaccione Sections. Newsl. Stratigr. 45/1, 75–103.

Gnibidenko, Z.N., Lebedeva, N.K., Shurygin, B.N., 2012. Paleomagnetism of the Cretaceous sediments of the southern West Siberian Plate (from well 8 core studies). Russian Geology and Geophysics (Geologiya i Geofizika) 53 (9), 895–905 (1169–1181).

Gnibidenko, Z.N., Lebedeva, N.K., Shurygin, B.N., 2014. A regional Upper Cretaceous magnetostratigraphic section of southern West Siberia (Omsk depression). Dokl. Earth Sci. 458 (1), 1107–1111.

Gnibidenko, Z.N., Lebedeva, N.K., Levicheva, A.V., 2015. Magnetostratigraphy of the Campanian-Maastrichtian Bakchar basin (southeastern West Siberia). Russian Geology and Geophysics (Geologiya i Geofizika) 56 (11), 1652–1661 (2092–2102).

Gnibidenko, Z.N., Levicheva, A.V., Semakov, N.N., Rusanov, G.G., 2017. Paleomagnetism and magnetostratigraphy of Upper Cretaceous and Cretaceous–Paleogene boundary intervals, southern Kulunda basin (West Siberia). Russian Geology and Geophysics (Geologiya i Geofizika) 58 (1), 87–98 (105–117).

Gurari, F.G., Volkova, V.S., Babushkin, A.E., Golovina, A.G., Nikitin, V.P., Nekrasov, A.I., Kriventsov, A.V., Dolya, Zh.A., Kolykhalov, Yu.M., Gnibidenko, Z.N., 2001. Unified Regional Paleogene and Neogene Stratigraphy of the West Siberian Plain. Chart and Explanatory Note [in Russian]. SNIIGGiMS, Novosibirsk.

Guzhikov, A.Yu., Baraboshkin, E.Yu., Ben'yamovskii, V.N., Vishnevskaya, V.S., Kopaevich, L.F., Pervushov, E.M., Guzhikova, A.A., 2017. New bio- and magnetostratigraphic data on Campanian-Maastrichtian deposits of the classical Nizhnyaya Bannovka section (Volga river right bank, southern Saratov region). Stratigr. Geol. Correl. 25 (1), 24–61.

Guzhikov, A.Yu., Molostovskii, E.A., Nazarov, Kh., Fomin, V.A., Baraboshkin, E.Yu., Kopaevich, L.F., 2003. Magnetostratigraphic data on the Upper Cretaceous of Tuarkyr (Turkmenistan) and their implications for the general paleomagnetic scale. Izv. Phys. Solid Earth 39 (9), 728–740.

Guzhikov, A.Yu., Baraboshkin, E.Yu., Fomin, V.A., 2007. Cretaceous magnetostratigraphy: state of the art, problems, and prospects, in: Pervushov, E.M. (Ed.), The Cretaceous System of Russian and Former Soviet Countries: Problems of Stratigraphy and Paleogeography, Collection of Papers [in Russian]. Saratov University, Saratov, pp. 69–86.

Guzhikov, A.Yu., Guzhikova, A.A., Manikin, A.G., Grishchenko, V.A., 2020. Magnetostratigraphy of the Maastrichtian from Volga Right Bank Area Near Saratov (Lower Volga Region), in: Yanovskaya, T.B., Kosterov, A., Bobrov, N.Yu., Divin, A.D., Saraev, A.K., Zolotova, N.V. (Eds.), Proceeding of the XII International Conference and School "Problems of Geocosmos–2018". Springer, Cham, pp. 83–105.

Guzhikova, A.A., Ben'yamovskii, V.N., 2018. The Campanian-Maastrichtian magnetostratigraphy of the Volga region (vicinity of Volsk town). Russian Geology and Geophysics (Geologiya i Geofizika) 59 (3), 276–284 (346–356).

Guzhikova, A.A., Guzhikov, A.Yu., Pervushov, E.M., Ryabov, I.P., Surinskiy, A.M., 2019. Existence of the reversal polarity zones in Turonian-Coniacian from the Lower Volga (Russia): New data, in: Nurgaliev, D., Shcherbakov, V., Kosterov, A., Spassov, S. (Eds.), Recent Advances in Rock Magnetism, Environmental Magnetism and Paleomagnetism, Springer Geophysics, Springer, Cham, pp. 353–369.

Iakovleva, A.I., Alexandrova, G.N., Gnibidenko, Z.N., 2012. The Paleogene Lulinvor Formation: new age constrainst from spore-pollen

and paleomagnetic data. Bul. MOIP, Ser. Geol. 87 (3), 53–87.
Lebedeva, N.K., Kuz'mina, O.B., 2018. Palynostratigraphy of the Upper Cretaceous and Paleogene Deposits in the South of Western Siberia by Example of Russkaya Polyana Boreholes, Omsk Trough. Stratigr. Geol. Correl. 26 (1), 80–108.
Lebedeva, N.K., Alexandrova, G.N., Shurygin, B.N., Ovechkina, M.N., Gnibidenko, Z.N., 2013. Paleontological and magnetostratigraphic data on Upper Cretaceous deposits from borehole no. 8 (Russkaya Polyana District, Southwestern Siberia). Stratigr. Geol. Correl. 21 (1), 43–73.
Lebedeva, N.K., Kuzmina, O.B., Sobolev, E.S., Khazina, I.V., 2017. Stratigraphy of Upper Cretaceous and Cenozoic deposits of the Bakchar iron ore deposit (southwestern Siberia): New Data. Stratigr. Geol. Correl. 25 (1), 76–98.
Lebedeva, N.K., Kuzmina, O.B., Khazina, I.V., Rusanov, G.G., Glinskikh, L.A., 2018. Palynological characteristic of Cretaceous–Cenozoic deposits in borehole Aleiskaya 23 on the south of Kulunda Depression (Western Siberia), in: Soil Use. Mining. Research Lines and Technology in Mineral Exploration. Geo-environment. Proc. XIV Intern. Conf., Interexpo GEO-Sibir-2018, Novosibirsk, 23–27 April 2018 [in Russian], in 6 volumes. SGUGiT, Novosibirsk, Vol. 1, pp. 175–182.
Lebedeva, N.K., Kuzmina, O.B., Khazina, I.V., Rusanov, G.G., Glinskikh, L.A., 2019. Palynostratigraphy and genesis of Upper Cretaceous and Cenozoic deposits in the southern part of the Kulunda Depression, Altai Region. Stratigr. Geol. Correl. 27 (6), 661–681.
Molostovskii, E.A., Khramov, A.N., 1997. Magnetostratigraphy and its Geological Implications [in Russian]. Saratov University, Saratov.
Nagata, T., 1961. Rock Magnetism. Mazuren Company, Tokyo.
Ogg, J.G., Ogg, G.M., Gradstein, F.M., 2016. A Concise Geologic Time Scale. Elsevier.
Pospelova, G.A., Larionova, G.Ya., 1971. Paleomagnetic study of sedimentary rocks of the Ilek Formation of the Chulym-Yenisei depression, in: The Earth's Crust of Folded Domains in Siberia [in Russian]. Novosibirsk, Issue 2, pp. 97–111.
Pospelova, G.A., Larionova, G.Ya., Anuchin, A.V., 1967. Paleomagnetic studies of the Jurassic and Lower Cretaceous rocks of Siberia. Geologiya i Geofizika, No. 9, 3–15.

Editorial responsibility: B.N. Shurygin