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A Stratigraphic Scheme for the Division of the Prequaternary Deposits of Central Crimea

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Abstract—A stratigraphic scheme for dividing the Triassic–Neogene deposits of the central Crimea by suites has been proposed. The division is based on the generalization of our own results and the analysis of the published and unpublished data.

Keywords: Mesozoic, Cenozoic, stratigraphy, Crimea
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INTRODUCTION

In spite of the long history of geological studies (since of the XVIII century) and abundance of data, the geological model and, as a consequence, the history of the development of Crimea have not been settled due to various issues. The current concepts, which consist of independent and unrelated models of the structure and evolution of the area, frequently contradict each other. This is mostly because various academic schools have different approaches to understanding the geology of Crimea. Therefore, no paradigm exists. The current work on the additional studies of the areas at scales of 1 : 1000000 and 1 : 200000 will encourage the unification of the concepts concerning the structure and evolution of the region.

The methods of this work included collection, analyses, and systematization of the unpublished, archived, and published materials; field observations; laboratory research; and office analysis.

Collection, analysis and systematization of the unpublished, archived, and published materials involved considering 329 published works, 24 reports, and 69 aerial images at a scale of 1 : 50000 and larger (up to 1 : 10000), as well as a huge set of factual and cartographic information. The primary data set (collected from archive sources) includes approximately 800 analytical laboratory tests, the materials of field observations (approximately 200 observation points), the data on stratotypes (key sections) with a total thickness of 900 m, information on mineral resources and geological–geophysical studies, and blocks of the additional data (320 measurements of rock fracturing, 102 dip and strike measurements, 863 measurements of magnetic susceptibility (*k*), 180 measurements of natural remanent magnetization (*Jn*), saturation remanent magnetization (*Jrs*), destructive field of saturation remanent magnetization (*H'cs*), and the increase of magnetic susceptibility after heating to 500°C in an air environment (*dk*), 81 tests on filtration-volumetric characteristics of rocks, description of 62 thin-sections, and approximately 600 items of graphic material (comparison schemes, stratigraphic columns, rhythmograms, etc.)).

In the course of the field surveying, 840 observation points have been described during 111 geological routes, 299 dip and strike measurements have been obtained, and 1736 photos have been made. All these data have been entered into the digital database.

The laboratory works consisted of the petrographic study of 25 thin-sections and overview of 100 thin-sections, palynological and diatomic analyses of 30 samples, microfauna analysis of 60 samples and macrofauna analysis of 75 samples, U–Pb dating (Secondary Ion Mass Spectrometer, Sensitive High-Resolution Ion Microprobe–SIMS, (SHRIMP)) on zircons (10 points) for 2 specimens, and determination of isotopic composition C + O in carbonates (55 samples).

In the course of the office analysis, the collections of rocks from the studied area (sheets L-36-XXVIII, L-36-XXIV, L-36-XXX, L-37-XIX, L-37-XXV, and L-37-XXXV) were considered; 1200 samples of organic remains, 1800 samples of rocks from the petrographic collection, and 200 samples of minerals have been studied. The geological, hydrogeological, geochemical, and geophysical state of knowledge of the area has been evaluated; the preliminary complex interpretation of the aerial and satellite images and the integrated interpretation of the geological–geophysical data, as well as the remote bases for the studying area have been made.

DISCUSSION

Due to the analysis of the published sources, several concepts can be highlighted to estimate the geological structure and evolution of the area. We absolutely do not believe that it is possible to solve the problems of stratigraphy and evolution of the region from the standpoint of "geological nihilism" starting from scratch, as has been accurately stated in (Yudin et al., 2015). This refers to the geological map of Crimea at a scale of 1 : 200000 (Popadyuk, 2013; Sheremet et al., 2014), on which the area of distribution of the Taurian series was shown as Lower Cretaceous deposits and Middle Jurassic intrusions occurred in the Lower Cretaceous deposits. To some extent, the selection of the concept or the model is a philosophical matter of belief in some concept; the model itself is our own simplified representation of the more complex reality. Let us consider the concepts of our predecessors.

1. According to the "tectonic" concept of V.V. Yudin (Yudin, 2006, 2009, 2011; Yudin and Gerasimov, 2001), tectonic mélange zones more than 100 km long and up to 10 km wide have been identified in the structure of Mountainous Crimea. Most geological boundaries were shown as tectonic structures (strippings and overthrusts). Many issues are clarified with the occurrence of the large mélange zones. Intrusive bodies occur within these zones. Under such an approach, it becomes unnecessary to "inscribe" the geological boundaries into the relief and it is possible to solve the problem of the variability in thickness and the bedding characteristics of the stratigraphic units–stratons.

S.B. Rozanov and V.S. Mileev (Moscow State University) (Mileev and Baraboshkin, 1999; Mileev et al., 2006, 2007, 2009) had similar views.

In our opinion, guided by the field observations and published data, not all tectonic boundaries are characterized by this type. Let us present the following concept to support this point of view.

2. In the concept of "structural formational zones" (Fikolina et al., 2008), tectonics is "one–two orders of magnitude lower" than in the preceding concept; however, there are many structural formational zones (SFZs) and each SFZ is composed of its own set of suites. The boundaries of the stratons are inscribed in the relief; their bedding characteristics and thicknesses are correlated.

We consider that under such an approach a stratigraphic framework becomes exceedingly cumbersome; there are a number of similar and poorly distinguishable suites and sequences that make it difficult to understand the geological structure and the development history of the area. In our view, it makes more sense that the variability of the composition and thickness of stratons is facial variation. It is difficult to imagine that, for example, in Late Cretaceous time, when the ocean level was high and the local structures were located over distances of tens of kilometers from one another, independent geological bodies were formed in these structures with no reference to the adjacent areas. Thus, it is necessary to admit that each structure had its own geological history.

In compiling the residual map through matching the western and eastern halves of the maps representing the first and the second concepts, it became clear that there is no single boundary to be traced: the stratigraphic boundaries run into mélange zones or dislocations.

There are other differences in the interpretation of the geological structure. Let us consider some examples. The complex geological structure of the area of the Demerdzhi Mountain is also a controversial issue and can be explained using several models. As an example, the block structure and the latitudinal normal fault between the Northern Demerdzhi and Southern Demerdzhi Mountains were noted by A.I. Uspenskaya (1969) and the overthrust structure was proposed by M.K. Bakhor (1992), V.S. Mileev et al. (2006, 2009), and V.V. Yudin (2009); however, according to their opinion, the architectures of these dislocations and their types are different (Rud'ko, 2014). The overthrust of the Tithonian limestones onto the Upper Jurassic conglomerates of the earlier age and the normal fault between these mountains were shown in the articles of V.S. Mileev et al. (2006, 2009). V.V. Yudin (2009) showed the wide zones of tectonic mélange developed in the area of the Jurassic outcrops. M.K. Bakhor (1992) described large dislocations of different types, normal fault–strike-slip faults, strike-slip fault–normal faults, and overthrusts (Rud'ko, 2014).

In spite of the roundup edition of the State Geological Map of Ukraine-200, the data represented in this publication are sometimes ambiguous and often contradictory. The same suites, located in different structural formational zones (for example, Demerdzhi suite) can have different ages, which probably can be explained by a technical mistake in compiling the map. Another example is the differing interpretations of the Belbek suite on different sheets of the map (L-36-XXVIII (Eupatoria), L-36-XXXIV (Sevastopol'), L-36-XXIX (Simferopol), L-36-XXXV (Yalta)) in one publication (Anfimova,

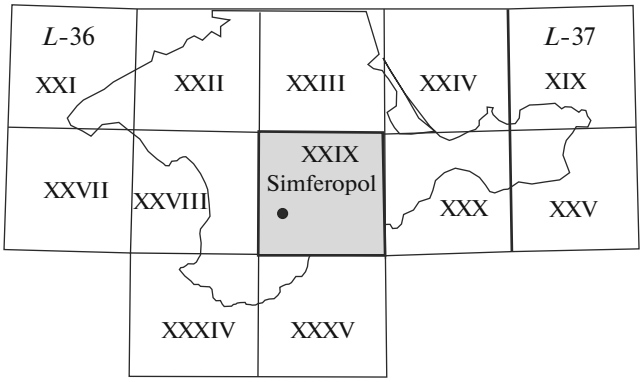

Fig. 1. The position of sheet L-36-XXIX in the Crimea sheet series at a scale of 1 : 200000.

2015). Figure 1 shows the layout of the sheets of the Crimean series.

However, we recognize that the team of the authors (now the Krymgeologiya State Unitary Enterprise) has carried out the tremendous job of the collection, analysis, and systematization of the unpublished, archive, and published materials along with their own field observations. The set of the maps with the explanatory note that they have prepared is an important step towards the further additional study of Crimea after the works of M.V. Muratov (Uspenskaya, 1969). Here, we consciously do not consider the works made before the publication of this map (Uspenskaya, 1969).

Thus, despite the efforts that have been made, many stratigraphic issues remain unresolved; there is no unified view regarding these issues. This shows the need for further research. Due to this, we mapped a number of suites of the Jurassic and younger systems as united and undifferentiated suites (along with other suites composing a single straton) in order to have the ability to divide them according to the results of future works.

We also consider that it is necessary to clarify the area of distribution of the Bodrak and Karadag suites in the piedmont and south-coast parts of sheet L-36-XXIX and on the adjacent areas (sheets L-36-XXV, L-36-XXX, L-36-XXXIV and L-36-XXVIII).

The research results of the geological structure (including the stratigraphic schemes) and evolution of Crimea were represented in the studied works (*Stratigrafiya*..., 1969; *Stratigraficheskii*..., 1979; *Geologiya*..., 1984; *Stratigraficheskaya*..., 1987; Nikishin et al., 1997; Panov, 1997, 2002; Nikishin et al., 1998a, 1998b, 2001, 2003, 2008, 2015; *Geologicheskaya*..., 2006; Beletsky and Belokrys, 2013; Popadyuk, 2013; Rud'ko, 2014; Anfimova, 2015; Okay and Nikishin, 2015). The article format does not allow us to give the description of the suites and the entire list of sources.

Therefore, there is no unified concept of the geological structure of the considering sheet. As a result of the work we carried out, structural formational zonation was performed for the Triassic, Jurassic, Lower Cretaceous, and Miocene deposits; the remaining stratigraphic interval was divided into suites without SFZs. The SFZ (Fig. 2) and the suite division (Table 1) were mostly adopted from the work (Fikolina et al., 2008) with a large set of generalized data; nevertheless, we made some corrections to this base. Figure 3 shows the schematic geological section.

In our view, it is time to specify the age of the suites of the Jurassic and Cretaceous systems and their ratios.

To solve this task, the following focus areas can be identified: (1) the additional analysis and reinterpretation (in the part of stratigraphic division) of the previously described sections of the Mesozoic deposits and (2) the execution of the special-purpose geological routes focused on revealing and mapping the possible

Fig. 2. The schemes of the structural formational zonation: (a) Zones for the Triassic and Jurassic: (*1*) Kacha–Salgir (*1.1*—subzones, Lozovoe, *1.2*—Bodrak (Kacha)); (*2*) Bitak; (*3*) Demerdzhi–Karabi; (*4*) Primorsk; (*5*) Privetnoye–Veseloye; (*6*) Sudak–Feodosiya; (b) Zones for the Early Cretaceous: (*1*) Kacha–Salgir; (*2*) Salgir–Chatyr-Dag; (*3*) Beshterec–Burul'cha; (*4*) Predgornaya; (c) zones for Pliocene: (*1*) Central; (*2*) Indol; (*3*) Alma; (*4*) Predgornaya; (*5*) Tuak.

Table 1. The stratigraphic scheme of division of the Prequaternary deposits of Central Crimea

NEOGENE SYSTEM **UPPER PLIOCENE**		
Central SFZ	**Alma SFZ**	**Predgornaya SFZ**
N_2ng—Nogaiskaya suite	N_2tv_2—Verkhnetavrskaya suite	N_2ng—Nogaiskaya suite
LOWER PLIOCENE		
Central SFZ	**Alma SFZ**	**Predgornaya SFZ**
$N_2br + čt$—Bagrationovskaya and Chatyrlitskaya sequence, joined	N_2tv_1—Nizhnetavrskaya suite	N_2br—Bagrationovskaya sequence
UPPER MIOCENE **PONT REGIONAL STAGE** N_2kz—Kazankovskaya sequence		
MEOTIS REGIONAL STAGE N_2bg—Bagerovskaya suite		
SARMAT REGIONAL STAGE **UPPER SUBSTAGE** N_1hr—Khersonskaya suite **LOWER AND MIDDLE SUBSTAGES** $N_1kp + bs$—Krasnoperekopskaya and Bessarabskaya suites joined		
LOWER MIOCENE N_1tc—terrigenous-carbonate sequence		
PALEOGENE SYSTEM **OLIGOCENE AND NEOGENE SYSTEM, LOWER MIOCENE** N_1mk_3—Maikopskaya series. Upper part		
PALEOGENE SYSTEM **OLIGOCENE** P_3–N_1mk_{1-2}—Maikopskaya series. Lower and middle parts		
UPPER EOCENE **BODRAK AND AL'MA REGIONAL STAGES** $P_2al + bd$—Al'minskaya and Bodrakskaya suites, joined		
LOWER AND MIDDLE EOCENE **YPRESIAN STAGE–LUTETIAN STAGE** $P_2bh + sm$—Bakhchisaraiskaya and Simferopol'skaya suites, joined		

Table 1. (Contd.)

PALEOCENE **DANIAN STAGE–THANETIAN STAGE** $P_2bk + kč$—Belokamenskaya and Kachinskaya suites, joined			
MESOZOIC ERATHEM **CRETACEOUS SYSTEM** **UPPER SERIES** **SANTONIAN STAGE–MAASTRICHTIAN STAGE** $K_2kd + ss$—Kudrinskaya and Starosel'skaya suites, joined			
CENOMANIAN STAGE–CONIACIAN STAGE $K_2bg + pr$—Belogorskaya and Prokhladnenskaya suites, joined			
LOWER SERIES **ALBIAN STAGE** **UPPER SUBSTAGE**			
Kacha–Salgir SFZ	**Salgir–Chatyr-Dag SFZ**	**Beshterek–Burul'cha SFZ**	**Belogorsk–Staryi Krym SFZ**
K_1mn—Mangush suite	K_1mn—Mamatskaya sequence	K_1ml—Melikhovskaya sequence	
LOWER AND MIDDLE SUBSTAGES			
	K_1sg—Salgir suite	$K_1kk + in$—Kurskaya and Indol'skaya sequences, joined	
HAUTERIVIAN STAGE. UPPER SUBSTAGE–APTIAN STAGE $K_1bs + kz$—Biasalinskaya and Koyasdzhildinskaya suites, joined	**BARREMIAN STAGE. UPPER SUBSTAGE–APTIAN STAGE** $K_1an + ms$—Angarskaya and Malosalgirskaya sequences, joined	**BARREMIAN STAGE. UPPER SUBSTAGE** K_1br—Burul'chinskaya sequence **LOWER SUBSTAGE** K_1mz—Mazanskaya suite **HAUTERIVIAN STAGE. UPPER SUBSTAGE** K_1zl—Zelenogorskaya sequence	**BARREMIAN STAGE. UPPER SUBSTAGE–APTIAN STAGE** $K_1st + gr$—Bogatovskaya and Topolevskaya sequences, joined
VALANGINIAN STAGE–HAUTERIVIAN STAGE K_1rz—Rezanskaya suite	**VALANGINIAN STAGE. MIDDLE AND UPPER SUBSTAGE–HAUTERIVIAN STAGE. LOWER SUBSTAGE** $K_1tk + bj$—Taskarinskaya and Biyukyankoiskaya sequences, joined	**VALANGINIAN STAGE. MIDDLE AND UPPER SUBSTAGE–HAUTERIVIAN STAGE. LOWER SUBSTAGE** $K_1mž + sv$—Mezhigirskaya and Solov'evskaya sequences, joined	**VALANGINIAN STAGE** $K_1st + gr$—Starokrymskaya and Gorlinskaya sequences, joined

Table 1. (Contd.)

JURASSIC SYSTEM UPPER SERIES TITHONIAN STAGE			
Demerdzhi–Karabi SFZ	**Primorsk SFZ**	**Privetnoye–Veseloye SFZ**	**Sudak–Feodosiya SFZ**
$J_3dm\$bk$—Demerdzhinskaya, Yaltinskaya and Bedenekyrskaya suites, joined	$J_3dm\$dj_1$—Demerdzhinskaya, Khutoranskaya suites and Dvuyakornaya suite, lower subsuite, joined		J_3mn—Mandzhil'skaya suite
UPPER SERIES. KIMMERIDJIAN STAGE–MIDDLE SERIES. BATHONIAN STAGE			
$J_{2-3}st + tp$—Stavlukharskaya and Tapshanskaya suites, joined	$J_{2-3}af + bp$—Bashparmakhskaya and Aifokinskaya suites, joined		$J_{2-3}kp + sd$—Kopsel'skaya and Sudakskaya suites, joined
MIDDLE SERIES BAJOCIAN STAGE			
Kacha–Salgir SFZ	**Bitak, Demerdzhi–Karabi, Primorsk and Privetnoye–Veseloye SFZ**		**Sudak–Feodosiya SFZ**
J_2bd—Bodrak suite	**UPPER SUBSTAGE.** J_2pr—Privetnenskaya suite		J_2kd—Karadagskaya suite
TRIASSIC SYSTEM. UPPER SERIES–JURASSIC SYSTEM. LOWER SERIES			
Kacha–Salgir SFZ			**Bitak, Demerdzhi–Karabi, Primorsk, Privetnoye–Veseloye and Sudak–Feodosiya SFZ**
Lozovoye subzone T_3–J_1es—Eskiordinskaya series	**Bodrak (Kacha) subzone** T_3–J_1tv—Tauric series		T_3–J_1tv—Tauric series
PALEOZOIC ERATHEM CARBONIFEROUS SYSTEM MIDDLE SERIES C_2ns—Novoselovskaya suite **LOWER SERIES** C_1zj—Zuiskaya suite			
NEO-PROTEROZOIC ERATHEM–PALEOZOIC ERATHEM VENDIAN AND CAMBRIAN SYSTEMS V–$Є ng$—Nizhnegorskaya series			

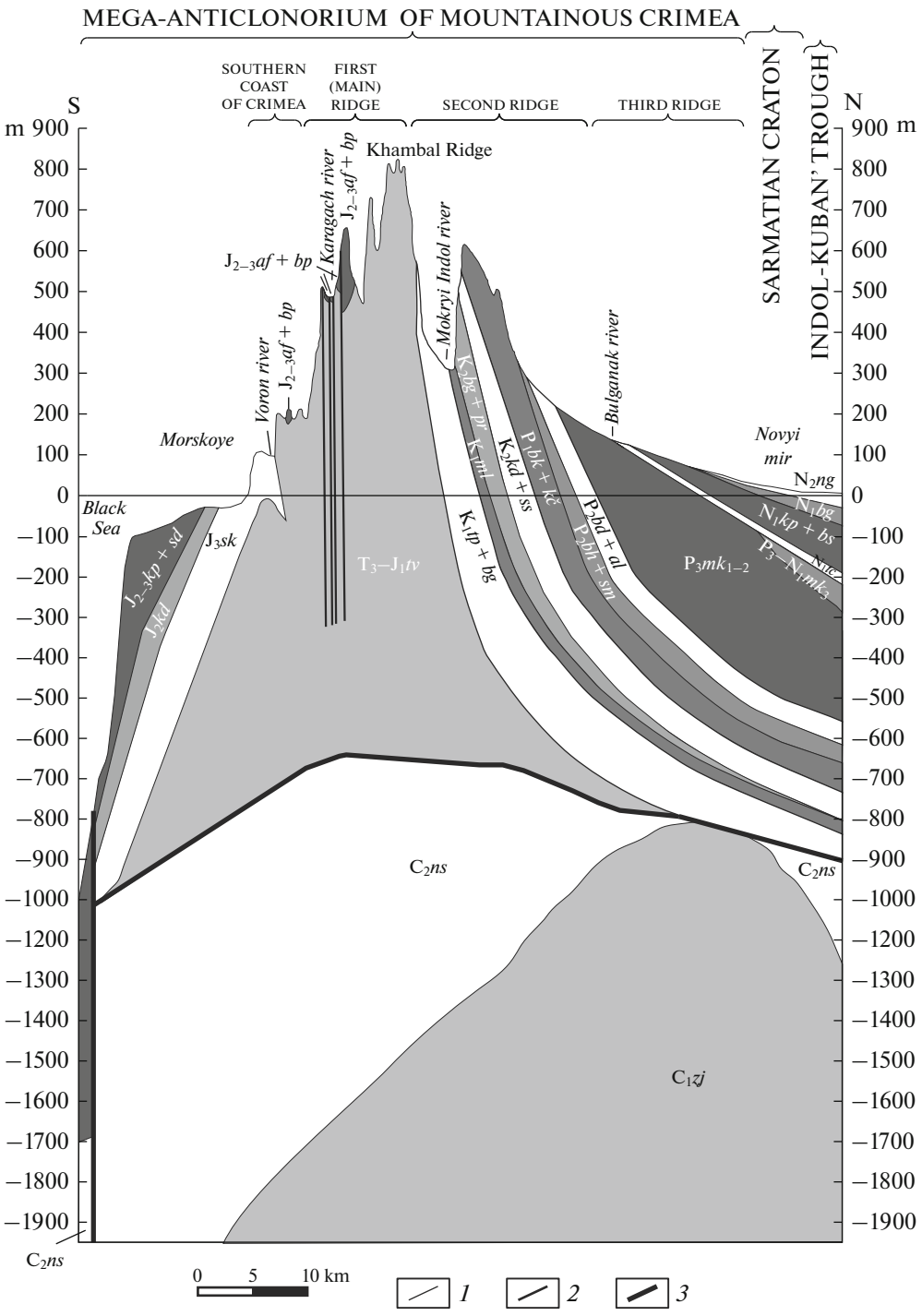

Fig. 3. The schematic geological section: (*1*) stratigraphic boundaries; (*2*, *3*) tectonic boundaries. The complete forms of the indices are in Table 1.

outcrops of the Triassic, Jurassic, and Cretaceous formations in the piedmont and plain parts of sheet L-36-XXIX and on the adjacent areas (sheets L-36-XXV, L-36-XXX, L-36-XXXIV, and L-36-XXVIII) with special studies to clarify the composition of the deposits and to collect additional information about their position in plan view and in the geological section.

CONCLUSIONS

A stratigraphic scheme for dividing the Prequaternary deposits into suites, and the schemes of the structural formational zonation for the Triassic–Jurassic, Early Cretaceous, and Pliocene of Central Crimea has been proposed as a result of the generalization of our

own data and the analysis of the published and archive sources.

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