

Stratigraphy
The Lochkovian–Pragian boundary in Podolia
(Lower Devonian, Ukraine) based upon placoderm vertebrates

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Abstract

Identifying stratigraphic boundaries within the Old Red Sandstones facies of Podolia (Ukraine) is problematic. Commonly used stratigraphic markers such as conodonts are indeed sparse or absent from this facies. The placoderm vertebrate *Kujdanowiaspis buczacziensis* (Brotzen, 1934) is proposed here as an index for the beginning of the Pragian. **To cite this article:** V. Dupret, A. Blicek, C. R. *Geoscience* 341 (2009).

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Résumé

La limite Lochkovien–Praguien en Podolie (Dévonien inférieur, Ukraine) d'après les vertébrés placodermes. L'établissement des limites stratigraphiques dans les Vieux Grès Rouges de Podolie (Ukraine) est relativement problématique, ce faciès se prêtant très mal à la fossilisation de marqueurs stratigraphiques habituels, comme les conodontes. La limite Lochkovien–Praguien (Dévonien inférieur) proposée ici correspond à l'apparition du vertébré placoderme *Kujdanowiaspis buczacziensis* (Brotzen, 1934). **Pour citer cet article :** V. Dupret, A. Blicek, C. R. *Geoscience* 341 (2009).

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Keywords: *Kujdanowiaspis*; Lochkovian; Placoderm; Pragian; Stratigraphic boundary; Vertebrate

Mots clés : *Kujdanowiaspis* ; Limite stratigraphique ; Lochkovien ; Placoderme ; Praguien ; Vertébrés

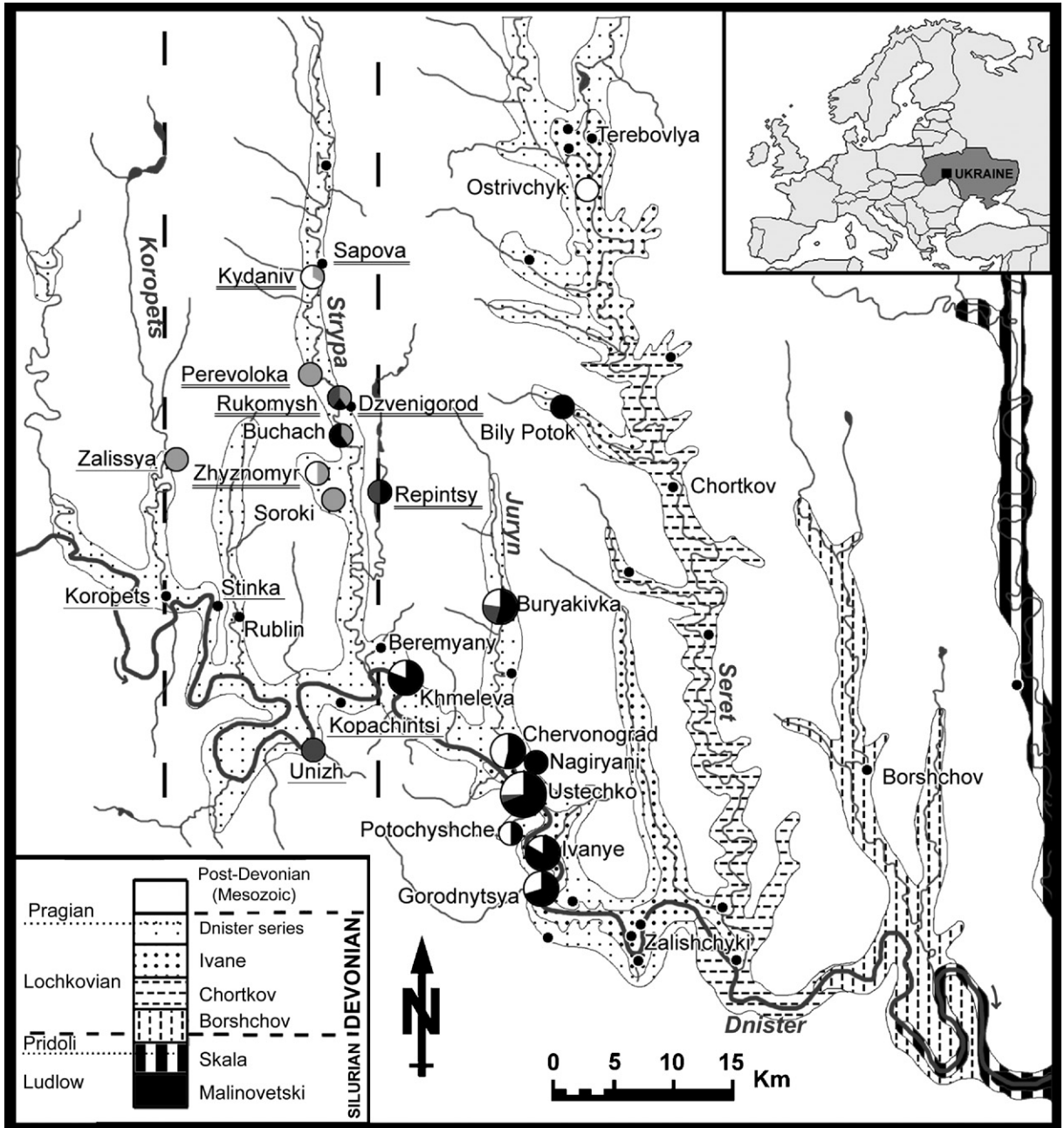
Foreword

The geopolitical status of Podolia has considerably changed during the past century as it was annexed by

Poland, and then restituted to Ukraine as a member of the former USSR, and more recently of the CIS. Hence, many changes have occurred in the spelling of the locality names by the use of different languages and alphabets (Polish, Russian, Ukrainian and English). In the following, we will only use the English transliteration. The different transliterations were compiled thanks to Elga Mark-Kurik (Institute of Geology,

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Number of studied specimens

- 1-10
- 11-50
- 51-100

STUDIED SPECIES

- *Kujdanowiaspis buczacziensis*
- *Kujdanowiaspis podolica*
- *Kujdanowiaspis* sp.
- "*Kujdanowiaspis*" *zychi*

ALTHASPIS DISTRIBUTION

- Repintsy *Althaspis elongata* locality
- Koropets *Althaspis* sp. locality

Fig. 1. Simplified geological map of Podolia (Ukraine) and distribution of the studied "actinolepid" species (modified after [2], compiled after [31], pl. I; [16]; [5], fig. 2; [19], figs 1–4; [21], fig. 4) and of the genus *Althaspis* (within the North–South oriented strip; after the data of [30]).

Tallinn Technical University, Estonia) and Daniel Drygant (Ukrainian National Academy of Sciences, Lviv), and are given in the appendix.

1. Introduction

Podolia has yielded numerous Late Silurian and Early Devonian vertebrate remains (see exhaustive references in [30]).

The “agnathan” fauna (thelodonts, heterostracans, osteostracans) is by far the most important, considering both the number of available specimens and their stratigraphic distribution. Acanthodians [13,14] and chondrichthyans [13,15] have also been reported. It is noteworthy that placoderms have hitherto never been used as stratigraphic markers. Ninety localities were identified in the Lower Devonian of Podolia, mostly exposed along the Dnister river and around Ternopol, Ivano-Frankivsk and Chernivetyky [30]. In this article, we will only retain the localities that yielded placoderm material.

2. Silurian–Devonian stratigraphy in Podolia

In Podolia, the Upper Silurian and Lower Devonian crop out as cuestas along the Dnister river and its northern tributaries. This series is unconformably overlain by Mesozoic (Jurassic and Cretaceous) and Cenozoic (Neogene) sediments. The whole Palaeozoic sequence is structurally organised as a gently westward dipping monocline [2,18] (Fig. 1).

The uppermost Silurian (Pridoli) includes the Malinovetski and Skala groups ([3], fig. 13). The Lower Devonian (Lochkovian and lower Pragian) is composed of the Borshchov, Chortkov and Ivane formations (Tiver “Super-Horizon”), and the Dnister “Series” (Fig. 2). This Dnister “Series” (or Babin Sandstones) is composed of the Old Red “unit” (classically divided into lower, middle and upper parts) and the Plant Group. The placoderm material was recovered from the Dnister “Series”; most specimens were collected on scree deposits. However, it is rather easy to reattribute most specimens to their original layers, based on the facies of their matrix.

The “actinolepid” arthrodires studied herein come from the Babin Sandstones. Their lithology is typically of Old Red Sandstone facies, with reddish to green sandstones to silty sandstones, and interlayered micac-

DNISTER SERIES	"BABIN SANDSTONE"	PLANT GROUP		Thelodonti, Heterostraci, Osteostraci, Placodermi
		OLD RED	reddish to greenish sandstones (lighter topward)	Thelodonti, Heterostraci, Osteostraci, Placodermi, Acanthodii
TIVER SUPER HORIZON	IVANE HORIZON		— red sandstones —	Thelodonti, Heterostraci, Osteostraci, Placodermi, Chondrichthyes
			schistous grey sandstones & greenish limestones alternance	
		CHORTKOV HORIZON	greenish grey limestone	Thelodonti, Heterostraci, Osteostraci, Placodermi, Chondrichthyes, Acanthodii
	BORSH-CHOV HOR.			Thelodonti

Fig. 2. Recapitulative table of the major lithic units of the Lower Devonian of Podolia, with main associated facies and faunas (after data from [2] [from [14,21,28]], [1,3,12,15,22,23]).

Fig. 2. Tableau récapitulatif des principales unités lithiques du Dévonien inférieur de Podolie (Ukraine), et principaux faciès et faunes associés (d’après les données de [2] [d’après [14,21,28]], [1,3,12,15,22,23]).

eous and argillaceous beds. The darkest red sandstones occur at the base of the series, and related fossils are lightly coloured. At the top of the series, rocks are lightly coloured, and fossils are darker. Brotzen [6], Narbutas [18], Karatajute-Talimaa ([14], and in [3]) intended to define the boundaries between the three parts of this lithostratigraphic series (Fig. 3). It is noteworthy that some localities are still problematic. These three parts (or “zones” Old Red I, II, III in the older literature) were originally defined on the basis of their different lithofacies [7,14,18]. However, Blicek [2] identified only two different faunas in these red beds, mainly based upon both heterostracans and placoderms.

Contrary to the latter study, three zones can be distinguished, based upon a taxonomic revision of the actinolepids [9]:

- a lower zone characterized by the occurrence of *Kujdanowiaspis podolica* (Brotzen, 1934) ([6]; Fig. 4A and B) and *Erikaspis zychi* (Stensiö, 1945; Fig. 4D and E) (Stensiö [29] described what he considered to be a new species of *Kujdanowiaspis*; however, an extensive study reveals that this taxon has to be considered as a new genus [11]);
- a middle zone containing *K. podolica*, *K. buczacziensis* (Brotzen, 1934) ([6]; Fig. 4C) and *E. zychi*;

Fig. 1. Carte géologique simplifiée de la Podolie (Ukraine) et répartition des espèces d’« actinolépidés » étudiés (modifié d’après [2], compilation d’après [31], pl. I; [16]; [5], fig. 2; [19], fig. 1–4; [21], Fig. 4) et du genre *Althaspis* (à l’intérieur de la bande orientée nord–sud ; d’après les données de [30]).

A	B	C	D	E
Brotzen 1936 (zones)	Narbutas (1984, P. 83)		Karatajute-Talimaa 1977	D. Goujet (pers. com.)
	SMERKLIV Fm	VISTRYA 15 (upper part of outcrop)	(pers. com. to D.Goujet)	
	DELAVA Fm	VISTRYA 15		
III	STRYPA Fm (100-150 m)		PEREVOLOKA DZVENIGOROD BUCHACH ZHYZNMIR	SOROKI BUCHACH ZHYZNMIR
		KHMELEVA 30 (banks 28-42)	BEREMYANY 11 (banks 20-25)	REPINTSY
			KYDANIV	KYDANIV
II	KHMELEVA Fm (40-60 m)	KHMELEVA 30 (banks 18-17)	BEREMYANY 11 (banks 15-19a)	REPINTSY
		KHMELEVA	USTECHKO (banks 26-47)	BURYAKIVKA
			USTECHKO 10 (banks 6-10)	
			MOGYLNYTSYA	
			CHERVONOGRAD	CHERVONOGRAD
I	USTECHKO Fm (80 m)	KHMELEVA (base of outcrop)	USTECHKO 10 (banks 1-5a)	
		USTECHKO 9		
		BILY POTOK		
		IVANYE	? BURYAKIVKA	
		ZALISHCHYCKI	POTOCHYSHCHE GORODNYTSYA	POTOCHYSHCHE GORODNITSYA USTECHKO
	IVANE Fm (126 m)			
				Lower ORS I - Lower ORS

unclear stratigraphic position: Koropets, Nezvyska, Ostrivchyk, Probabin, Pidgaychyky, Rabrovets, Rizdvany, Rukomysh, Soroki, Torske, Unizh, Voiskie, Zalissya.

Fig. 3. Zonation of the *Babin Sandstones* or *Old Red Sandstones* (ORS) considered by (A) [6,7], (B, C) [18], (D) Karatajute-Talimaa ([14] and unpublished data), and (E) D. Goujet's (*pers. com.* after unpublished data taken from the collection of V. Karatajute-Talimaa, Institute of Geology and Geography, Lithuania). Problematic localities in grey. Compiled by E. Mark-Kurik.

Fig. 3. Zonation des *Grès de Babin* ou *Old Red Sandstones* (ORS) considérés par (A) [6,7], (B, C) [18], (D) Karatajute-Talimaa ([14] et données non publiées), et (E) D. Goujet (*com. pers.*, d'après des notes inédites prises dans les collections de V. Karatajute-Talimaa, Institut de géologie et de géographie de Lituanie). Les localités problématiques sont indiquées en grisé. Compilé par E. Mark-Kurik.

- an upper zone characterized by the presence of *K. buczaciensis* only (Fig. 4F).

3. The Silurian–Devonian (Pridoli–Lochkovian) boundary

Many geologists have been interested in the Silurian–Devonian succession of Podolia, because the marine sedimentation is continuous through the Pridoli–Lochkovian [20,24]. The base of the Devonian in Podolia coincides with the first occurrence of:

- the graptolite *Monograptus uniformis uniformis* [17] at the top of the Tajna Formation, just below the boundary with the Mitkov Formation [3,21];
- the chitinozoan *Eisenackitina bohemica* (assemblage 4 of [26]; [27], fig. 13; in [3], p. 244);
- the thelodont *Turinia pagei* [14].

Therefore, the base of the Lochkovian would be situated just above the top of the Borshchov Formation.

It is noteworthy that the stratigraphic series through the Silurian–Devonian boundary near the villages of

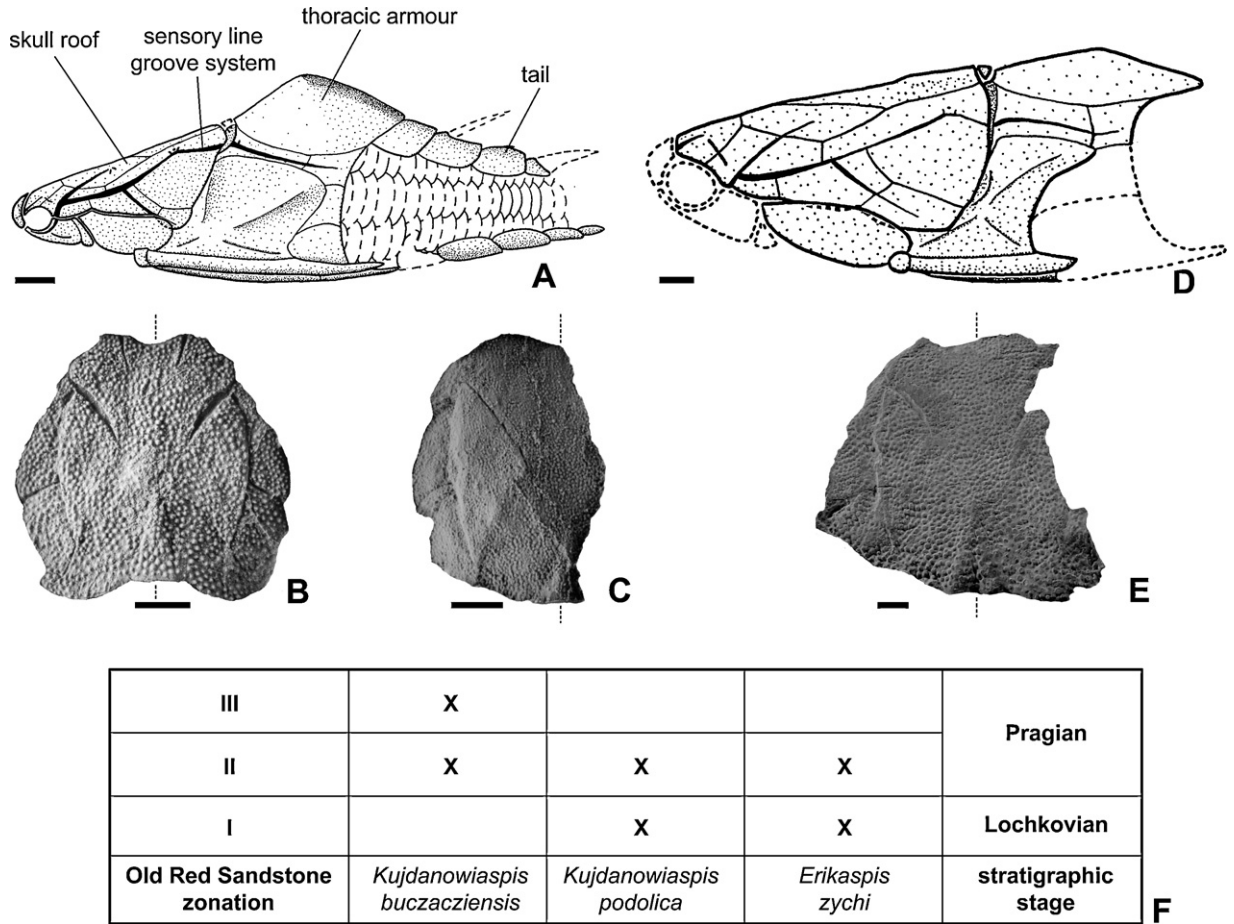


Fig. 4. The three species of arthrodire placoderms involved in the Lochkovian–Pragian boundary in Podolia. A–B. *Kujdanowiaspis podolica* (Brotzen, 1934). C. *Kujdanowiaspis buczacziensis* (Brotzen, 1934). D–E. *Erikaspis zychi* (Stensiö, 1945). F. Stratigraphic distribution. A and D in left lateral view. B, C, E are subcomplete to incomplete dermal bony skull roofs in dorsal view. *K. podolica* and *K. buczacziensis* only differ in size and in the density and size of the tuberculated ornamentation. The dermal plate pattern of *E. zychi* differs from that of the genus *Kujdanowiaspis*. Midplanes of symmetry indicated on B, C, E in dashed lines. A modified from [10]: fig. 5; B modified from [9]: pl. 13A, specimen NHM P 18228; C modified after [9]: pl. 27A, specimen Pi 1204; D modified after [11]: fig. 3B; E modified after [11]: fig. 6C, specimen NHRM P 28559. The illustrated specimens are curated in: NHM, Natural History Museum, London, United Kingdom; NHRM, Naturhistoriska Riskmuseet, Stockholm, Sweden; Pi, Paleontological Institute, Tallinn, Estonia. All scale bars equal 1 cm.

Fig. 4. Les trois espèces de placoderme arthrodire évoquées dans le problème de la limite Lochkovien–Praguien en Podolie. A–B. *Kujdanowiaspis podolica* (Brotzen, 1934). C. *Kujdanowiaspis buczacziensis* (Brotzen, 1934). D–E. *Erikaspis zychi* (Stensiö, 1945). F. Répartition stratigraphique. A et D en vue latérale gauche. B, C, E : toits crâniens dermiques et osseux en vue dorsale, subcomplets à incomplets. *K. podolica* et *K. buczacziensis* ne diffèrent que par leur taille et par la densité et la taille des tubercules composant l'ornementation dermique. *Erikaspis zychi* se distingue notamment du genre *Kujdanowiaspis* par un patron du toit crânien différent et une tuberculation plus grossière. Les plans de symétrie bilatérale sont indiqués en pointillés sur B, C, E. A modifié d'après [10] : fig. 5 ; B modifié d'après [9] : pl. 13A, spécimen NHM P 18228 ; C modifié d'après [9] : pl. 27A, spécimen Pi 1204 ; D modifié d'après [11] : fig. 3B ; E modifié d'après [11] : fig. 6C, spécimen NHRM P 28559. Les spécimens illustrés sont conservés au : NHM, Natural History Museum, Londres, Royaume-Uni ; NHRM, Naturhistoriska Riskmuseet, Stockholm, Suède ; Pi, Paleontological Institute, Tallinn, Estonie. Toutes les barres d'échelles égale 1 cm.

Volkovsky and Khudkovsky, on the northern edge of the Dnister river [21], differs from the GSSP of Klonk in the Barrandian basin (Czech Republic). According to Nikiforova [21], only the appearance of the trilobite *Acastella heberti* and the disappearance of the brachiopod *Dayia bohémica* coincide with the appearance of the graptolite *M. uniformis angustidens* at the

base of the Tajna Formation and at the Silurian–Devonian boundary. Because of the biodiversification observed above this boundary, Nikiforova does not consider the appearance of *M. uniformis uniformis* as an index of the Lochkovian. Nevertheless, she recognizes that the Tajna Formation contains exclusively Pridolian fossils as compared to the Barrandian of Bohemia.

4. The Lochkovian–Pragian boundary

This boundary is more difficult to establish than the former one. According to the ICS, the Pragian starts with the appearance of the conodont *Eognathus sulcatus sulcatus* ([25], in [4], Tab. 2, p. 8). However, the Old Red Sandstone facies of the Babin Sandstones does not allow the preservation of such a biostratigraphic marker.

In Podolia, the Lochkovian–Pragian boundary was roughly correlated with the boundary between the Old Red I and II “zones” [2], according to the occurrence of the pteraspideid *Althaspis elongata* [31]. The genus *Althaspis* itself is present across the Lochkovian–Pragian boundary in western Europe (Fig. 1; [2], figs. 67, 71–73; [3], p. 246). In Podolia, *A. elongata* is collected in several localities which correspond to a roughly north–south orientated outcropping strip, from Beremyany in the east to Koropets in the west (Fig. 1). This strip displays in the field the Lochkovian–Pragian transition.

Considering the actinolepid placoderms, it is remarkable that *Kujdanowiaspis podolica* and *Erikaspis zychi* are situated in the eastern part of this strip and eastward from it, and that *K. buczacziensis* is found in its middle and western parts (Fig. 1). These taxa have thus a biostratigraphic value as well. When Brotzen [6] erected several new species of “acanthaspids”, he also provided their preliminary stratigraphic distribution. Denison [8] used all the arthrodire species too: *K. podolica*, *K. buczacziensis*, but also *K. rectiformis*, *Phlyctaenaspis extensa*, *Acanthaspis prominens*,

A. vomeriformis and *A. angusta* (those latter being considered as junior synonym of *K. podolica* and *K. buczacziensis* by Dupret [9]).

5. Conclusion

It is proposed here to characterize the beginning of the Pragian with the appearance of *K. buczacziensis* (Brotzen, 1934) (Fig. 4F). However, most of the specimens come from the base of the series, and only few specimens can be assigned with certainty to *K. buczacziensis*. As a conclusion, we consider that *K. podolica* and *E. zychi* are almost certainly Late Lochkovian and probably Early Pragian in age, and that *K. buczacziensis* is almost certainly Early Pragian in age.

Acknowledgments

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Appendix. English transliteration (from Ukrainian) for locality names

English transliteration	Ukrainian	Russian	Polish	explanation
Barysh	Бариш	Барыш	Baryszka	river, Dnister Basin
Beremyany	Беремяни	Беремьяны	Beremiany	locality, Strypa Basin
Bila	Била	Белая	Biała	river, Seret Basin
Bily Potik	Білий Потік	Белый Поток	Białe Potok = Potok Biały	locality, Seret Basin
Buchach	Бучач	Бучач	Buczacz	locality, Strypa b.
Buryakivka	Буряківка	Бураковка	Burakówka	locality, Juryn b.
Chervonograd	Червоноград	Червоноград	Chervonogród	locality Juryn b.
Chortkiv	Чортків	Чортков	Czortków	town
Dniester	Дністер	Днестер	Dniester	river
Dzvenygorod	Дзвенигород	Дзвенигород	Dźwinogród	locality, Strypa b.
Gorodnytsya	Городниця	Городница	Horodnica	locality, Dnister b.
Ivanye	Іване	Иване = Иване-Золотое	Iwanie	locality, Dnister b.
Juryn	Джурин	Джурин	Dżuryn	river, Dnister b.
Jurynka	Джуринка	Джуринка	Dżurynka	ruisseau, Juryn b.
Khmeleva	Хмелева	Хмелевая	Chmielowa	locality, Dnister b.
Kopachinski	Копачинці	Копачинци	Ā	locality, Dnister b.
Khomyakivka	Хом’яківка	Хом’яковка	Chomiakówka	locality, Seret b.

Appendix (Suite)

English transliteration	Ukrainian	Russian	Polish	explanation
Koropets	Коропець	Коропец	Koropiec	locality, Koropets b.
Kydaniv	Киданів	Киданов	Kujdanów	locality, Strypa b.
Mogylnytsya	Могильниця	Могильница = Трудовое	Mogielnica	locality, Seret b.
Nagiryani	Нагірянні	Нагиряни	Å	locality, Juryn b.
Nezvyska	Незвиска	Незвиска	Niezwiska	locality, Dnister b.
Ostrivchyk	Острівчик	Островчик	Ostrowczyk	locality, Seret b.
Perevoloka	Переволока	Переволока	Przewłoka	locality, Strypa b.
Pidgaychyky	Підгайчики	Подгайчики	Podhajczyki	locality, Seret b.
Potochyshe	Поточище	Поточище	Potoczyska	locality, Dnister b.
Probabin	Пробабин	Пробабин	Probabin	locality, Dnister b.
Rabrovec	Å	Рабровеч	Rabriowiecz	locality, Dnister b.
Repintsy	Репінці	Репинцы	Rzepińce	locality, Strypa b.
Rizdvyanu	Різдвяни	Рездвяны	Ruzdwiany	locality
Rublin	Рублін	Рублин	Å	locality
Rukomysh	Руломиш	Рукомыш	Rukomysz	locality, Strypa b.
Sapova	Сапова	Сапова	Sapowa	locality, Strypa b.
Seret	Серет	Серет	Seret	river
Smerkliv	Смерклів	Смерков	Smerków	river, Dnister b.
Soroky	Сороки	Сороки	Soroki	locality, Strypa b.
Stinka	Стінка	Стинка	Å	locality, Dnister b.
Strypa	Стрипа	Стрыпа	Strypa	river
Terebovlya	Теребовля	Теребовля	Trembowla	town, Seret b.
Ternopil	Тернопіль	Тернополь	Tarnopol	town
Torske	Торське	Торское	Torskie	locality, Dnister b.
Unizh	Уніж	Униж	Uniz	locality, Dnister b.
Ustechko	Устечко	Устечко	Uściczko = Wojskie	locality, Dnister b.
Vilkhovets	Вільховець	Ольовец	Olchowiec	river, Strypa b.
Vistrya	Вістрія	Вистря	Ostra	locality, Dnister b.
Zalishchyki	Заліщики	Залещики	Zaleszczyki	locality, Dnister b.
Zalissyа	Залісся	Залесье	Zalésie	locality, Koropets b.
Zhyznomyr	Жизномир	Жизномер	Żyżnomierz	locality, Strypa b.
Zolota Lypа	Золота Липа	Золотая Липа	Złota Lipa	river

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