

## Earliest world record of green lizards (Lacertilia, Lacertidae) from the Lower Miocene of Central Europe

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**Abstract:** The earliest world record of the green lizards, *Lacerta viridis* group, is described from the lower Miocene of Central Europe. The fossils come from greenish, calcareous marls and limnic clayey silts of the Ottnangian zone MN 4 of the Dolnice locality near Cheb in the Czech Republic. Sediments are interpreted as marginal, riparian facies. The material consists of isolated frontal bones of two different ontogenetic stages and one isolated fragment of parietal. Their morphology is identical to that of the extant members of the *L. viridis* group. However, the fossil material is much older than the previously described specimens of green lizards. Therefore, this finding extends our knowledge about the evolution and stratigraphic range of the group and about composition of the early Miocene herpetofauna in central Europe.

**Key words:** *Lacerta viridis* group; morphology; Ottnangian; Dolnice; Czech Republic

**Abbreviations:** Pb and NMP 6V number – Collection of the National Museum, Prague, Czech Republic; DE – Collection of Department of Ecology, Comenius University, Bratislava, Slovakia; MN – Mammal Neogene zone.

### Introduction

The lizard family Lacertidae Oppel, 1811 consists of about 280 species and is found widely in Eurasia and Africa (Arnold et al. 2007). Recent molecular analyses using DNA sequences suggest it may be the sister-group of the Amphisbaenia, the worm lizards (Townsend et al. 2004; Vidal & Hedges 2004). This paper deals with the oldest occurrences of lizards close to the *Lacerta viridis* group (green lizards) from the Lower Miocene of the Dolnice locality near Cheb in westernmost Bohemia (Czech Republic). As a result of recent studies, the former *Lacerta viridis* (Laurenti, 1768) has been split into *L. viridis* (sensu stricto) and *L. bilineata* Daudin, 1802, based first on the results of hybridization experiments (Rykena 1991) and later by both protein electrophoretic data (Amann et al. 1997) and mitochondrial DNA (mtDNA) sequences (Brückner & Düring 2001). This group includes medium-sized lacertids. Similar species include especially the Balkan green lizard or three-lined green lizard *Lacerta trilineata* Bedriaga, 1886, the Caucasus green lizard *L. strigata* Eichwald, 1831 and Schreiber's green lizard or the Iberian Emerald lizard *Lacerta schreiberi* Bedriaga, 1878. According to morphological studies (Schmidtler 1986), *L. trilineata* was recently split into three species, *L. trilineata*, Levant green lizard *L. media* Lantz et Cyrén, 1920 and Turkish pamphylic green lizard *L. pamphylica* Schmidtler, 1975.

Fossils of the green lizard group are not so common. A number of authors in the past described materials of

green lizards at the species level; however, they probably should have been more cautious. Bolkay (1913) described fossil bones from the Upper Miocene sediments (the Pannonian) of Hungary and Romania, which he referred to the contemporary species *L. viridis*. However, Estes (1983) demonstrated that the oldest undeniable remains of this species are from Upper Pliocene of Hungary and Sicily. The oldest known remains of *L. cf. viridis* were described on the basis of several isolated dentaries and maxillae from the late Miocene (MN 11) localities of Kohfidisch in Austria (Tempfer 2004) and Polgárdi in Hungary (Venczel 2006). The great majority of fossil *L. viridis*, however, are documented from the late Pliocene (Ivanov 2007) and Pleistocene of Europe (Bonfiglio et al. 2002). The new material of green lizard as described below from the lower Miocene locality of Dolnice near Cheb (MN 4b) is much older than previously described specimens and, therefore, our knowledge of its evolution is expanded by providing new data on its spatial and temporal ranges and morphology.

### Material and methods

This study is based on the fused frontals Pb 02054, a fragment of the left frontal Pb 02055 and a fragment of a posterior right portion of parietal Pb 02024. All these fossils are housed in The National Museum, Prague, Czech Republic. The material was collected from the Lower Miocene (Ottnangian) sediments, zone MN 4b, of the Dolnice locality near Cheb, Czech Republic, by screen-washing or surface prospecting.

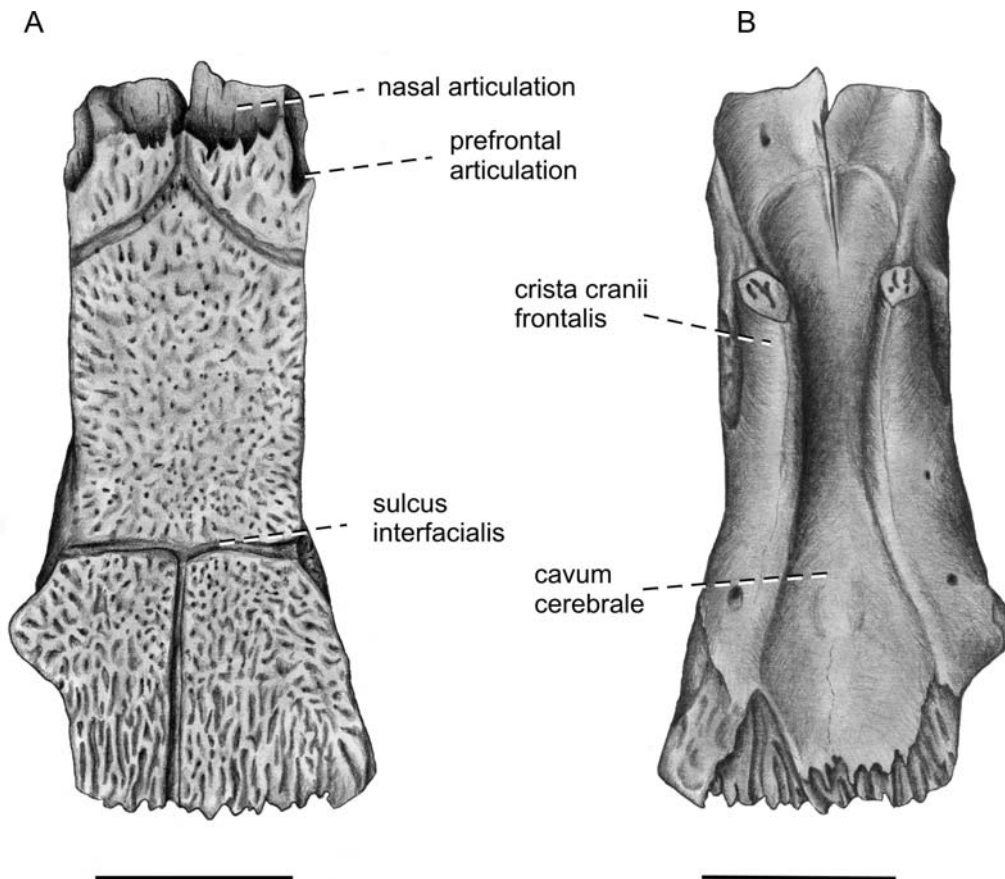


Fig. 1. Fused frontals Pb 02054 of the early Miocene adult individual of the green lizards *Lacerta* group *L. viridis*: A – dorsal view; B – ventral view. Scales 5 mm.

The following specimens of the extant lacertid species in the collections of the National Museum in Prague and the Department of Ecology, Comenius University in Bratislava, Faculty of Natural Sciences, have been used for comparisons: *Lacerta viridis* NMP 6V 22115, 22134, 22137, 22139, 22144, 23595, 23596, 23601, 23603, 23604, DE 51; *Lacerta agilis* NMP 6V 23661, 23664, 33667, DE 78–79 and *Timon lepidus* (= *Lacerta lepida*) NMP 6V 23179, 23181, 23182, 23185, 23589, 23590. Comparisons are also based on descriptions and illustrations, especially of cranial bones of extant *Podarcis muralis* and *Zootoca vivipara*, in Rauscher (1992).

#### Geological settings

The Dolnice locality is located in the westernmost part of the Cheb basin near the town of Cheb. The fossils are derived from greenish, calcareous marls and limnic clay silts of the Lower Miocene (Ottangian) zone MN 4 and are interpreted as marginal, riparian facies (Fejfar & Kvaček 1993). The fossil-bearing deposits are exposed at several sites in the roof of the local, main, brown coal seam of the basin. In addition to lacertids, the locality has yielded a rich abundance of other fossil lizards, such as chameleonids, cordylids, and agnuids (e.g., Klembara 1979, 1981; Roček 1984).

#### Results

Scincomorpha Camp, 1923  
 Lacertidae Oppel, 1811  
*Lacerta* L., 1758  
*Lacerta* group *L. viridis*

#### Description

**Frontal.** Description is based on a fused frontal, Pb 02054 (Fig. 1), and a single frontal Pb 02055. The frontal is elongated, rectangular in shape. Its postero-lateral corners are wedge-shaped. It is massively built and narrow relative to its length. The anterior portion is much longer than the posterior one (Fig. 1A). The posterior portion of the frontal is wide and its entire posterior margin contacts the parietal. This suture is almost straight in the fused frontals but gently convex in the isolated one. The entire dorsal surface of the frontal has a light ornamentation, which is more strongly expressed in its posterior portion. The dorsal ornamentation is formed by small, numerous grooves, ridges, and minute protuberances. Foramina are abundantly distributed over the entire surface. On the posterior portion of the frontal, the minute foramina gradually become transformed into small, shallow grooves that are oriented posteriorly and posterolaterally. Two elongated, unornamented, oval surfaces that are separated by an anteroposteriorly elongated short median spur are developed on the anterior edge of the fused frontals. The unornamented surfaces are the sutural facets for the nasals, which were separated posteriorly by the median spur. On the ventral surface beneath the median spur is a prominent V-shaped groove. Posteriorly it continues dorsolaterally to the lateral margins of

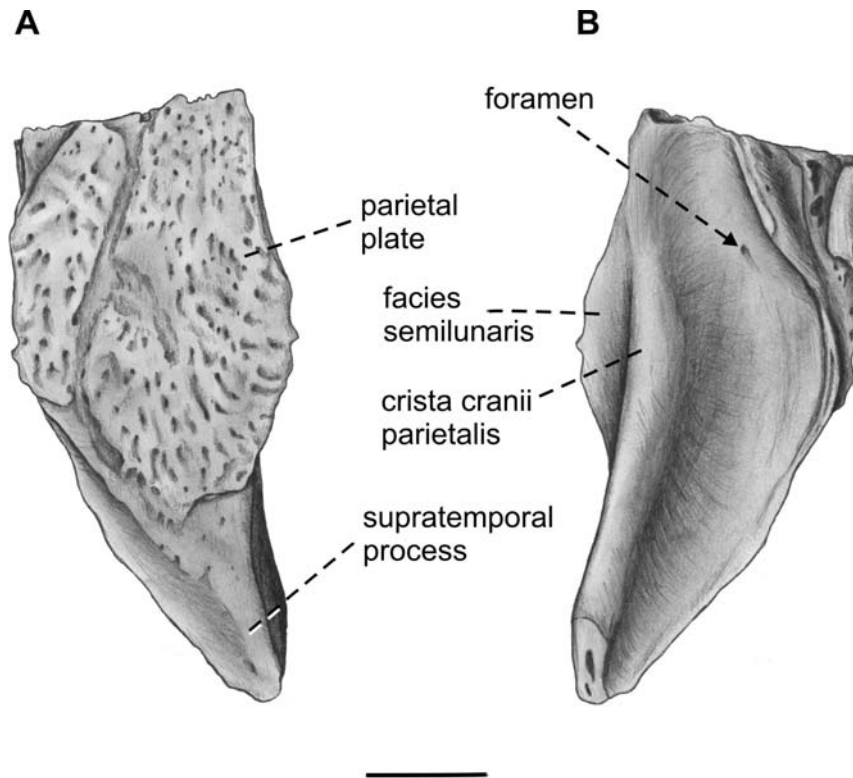


Fig. 2. A fragment of the posterior right portion of parietal Pb 02024 of the green lizard *Lacerta* group *L. viridis*: A – dorsal view; B – ventral view. Scale 2 mm.

the bone. It demarks the facets for the prefrontal and frontal osteodermal plates. Narrow prefrontal facets are present as small wedges on the anterior part of the lateral margins. The posterior portion of the bone, which widens gradually, is separated from the anterior portion by a distinct, transverse groove called the *sulcus interfaccialis*. It demarcates the border between the frontal and the more posteriorly located frontoparietal osteodermal plates. From its midlength another groove extends posteriorly to subdivide the posterior portion.

On the ventral surface the *cristae cranii frontale* are well developed (Fig. 1B). The massive crista is most ventrally extensive in its anterior half, ending in a truncated margin in the anterior third of the bone as the *processus palatinus*. For this reason, the *cavum cerebrale* is bordered anteriorly only by a very shallow, arched ridge. Farther posteriorly the *crista cranii* becomes gradually less well developed. The median suture of the largely co-ossified frontals is discernible only on the smooth ventral surface, especially in its anterior portion. The *facies sphenoidalis* is wide. The position of the former suture of the conjoined frontals in Pb 02054 is discernible only on the ventral surface.

#### *Ontogenetic remarks*

Two ontogenetic growth stages are represented by the fused frontals Pb 02054 and the single left frontal Pb 02055. The smaller, incompletely preserved left frontal Pb 02055 has a posterior width of 5.4 mm and a midlength width of 3.6 mm. The nearly complete fused frontal pair Pb 02054 has a length of 19.1 mm, a width

of the anterior portion, as well as the *sulcus interfaccialis*, of 6.6 mm, and a width of the incomplete posterior end of 9.2 mm. Pb 02055 probably represents a late juvenile or subadult ontogenetic stage of development, whereas Pb 02054 undoubtedly represents an adult ontogenetic stage.

**Parietal.** The parietal is a large azygous element consisting of the parietal plate with an ornamented surface, and two posterolaterally diverging supratemporal processes. Description is based on a fragment Pb 02024 of the right posterior portion of the parietal (Fig. 2). The ornamentation of the parietal plate is identical to that of the frontals described above (Fig. 2A). The preserved portion of parietal plate is divided by a distinct, medially arched groove. It demarcates the border between the parietal and interparietal osteodermal plate. The occipital plate is not preserved. The supratemporal process continues posterolaterally. However, it is incomplete. The distal tip is broken and missing. On the ventral surface of the parietal, the *crista cranii parietalis* runs along the lateral margin of the supratemporal process. The *crista cranii* continues at the level of the parietal plate and becomes gradually less well developed. The rest is broken and missing. The *crista cranii* forms the border between a medial depression and a lateral *facies semilunaris* (Fig. 2B).

#### **Comparisons**

The material has features identical to those of green lizards of the *Lacerta viridis* group. However, for ex-

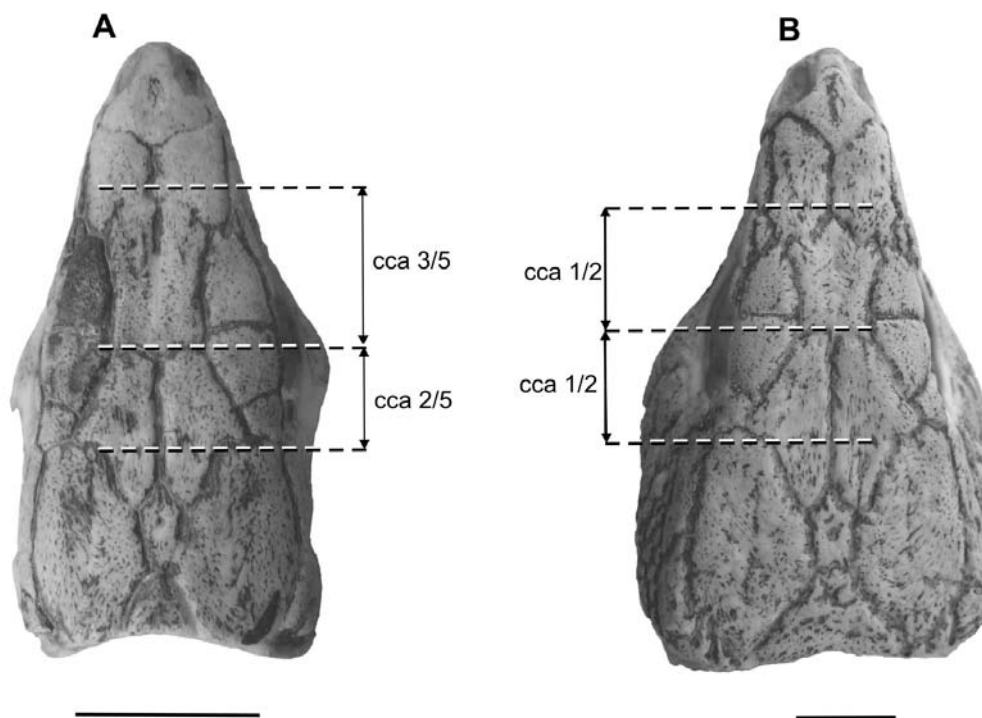


Fig. 3. Different proportion of the anterior and the posterior frontal portions of the Recent European lacertids: A – *Lacerta viridis* NMP 6V 23601; B – *Timon lepidus* NMP 6V 23179. Scales 10 mm.

ample *L. trilineata* can be very difficult to distinguish from *L. viridis*, especially as both are very variable. The exact identification of the isolated green lizard skull bones from the Lower Miocene of Dolnice locality at the species level is impossible. For this reason, in the following section the comparison of frontals with other typical European common lacertids, besides of green lizards, is done (outgroup comparison).

The frontal of extant *L. agilis* and the frontal described in this paper can be distinguished in the following ways:

1) The sculpturing of the extant *L. agilis* differs in consisting mainly of larger protuberances, pustules, and distinctive irregular grooves.

2) The frontal bone referred here is much bigger. It is robust, but narrow relative to its length. The frontals of *L. agilis* are broader relative to their length.

3) The crista cranii of the *L. agilis* is not as massively developed as in the *L. viridis* group.

The frontal bone of extant *Timon lepidus* and the frontal described in this paper can be distinguished in the following ways:

1) The anterior portion before the *sulcus interfaccialis* of the frontal bone of *T. lepidus* forms approximately 1/2 of the whole length of the bone (Fig. 3B). For this reason, the posterior portion is more robust. The proportions of the anterior and posterior portion are approximately 1:1. The anterior portion before the *sulcus interfaccialis* of green lizards is distinctly longer than the posterior one (Fig. 3A). Their proportions are approximately 3:2, in some individual cases even nearly 3:1 [see, e.g., in Bruner et al. 2005; Bruner & Costantini 2009 (Fig. 7c)].

2) *T. lepidus* has very similar, but generally more distinctive sculpturing, consisting mainly of foramina and sharply defined grooves on the posterior portion of the frontal, as well as on the portion of the nasal bordering the frontal. The grooves radiate from the ossification centers. The intensity of the sculpturing can be variable between the individuals of these two species and depends also on the ontogenetic level.

3) They differ in size (see Barbadillo & Sanz 1983; Barahona & Barbadillo 1997).

The frontal of extant *Podarcis muralis* and the frontal described in this paper can be distinguished in the following ways:

1) A distinctive feature of the frontal bone in *P. muralis* is its midlength constriction and therefore its lateral margins are clearly arched. The lateral margins of the anterior portion of the frontal bone of green lizards are generally straight. Only in some individual cases are the lateral margins gently constricted near the level of the *sulcus interfaccialis*.

2) A similar, but generally less pronounced and widespread, type of sculpture is present in extant *Podarcis muralis*. It consists mainly of foramina that are only occasionally accompanied by grooves, especially on the lateral margin of the frontal bone.

The frontal of extant *Zootoca vivipara* and the frontal described in this paper can be distinguished in the following ways:

1) The sculpturing of the extant *Z. vivipara* differs in consisting mainly of wider flat pustules and distinctive irregular grooves and foramina.

2) The frontal bone referred here is much bigger.

The frontal bone of *Z. vivipara* is shorter relatively to its width than the frontal referred here.

### Discussion and conclusion

The fused frontals from an adult individual and single frontal from subadult are identical to those in the extant species of green lizards close to *Lacerta viridis* group. It is well known that the current genetic pattern of many European species has been highly influenced by climatic changes during the Pleistocene. Böhme et al. (2007) suggested that the west Balkan lineage represents an early offshoot of *L. bilineata* that was isolated during a previous Pleistocene glacial from the more western *L. bilineata* populations, which survived in refuges on the Apennine peninsula. For this reason, the exact determination of the isolated osteological green lizard material from the Lower Miocene at species level is impossible. The genus *Timon*, which can occur together with green lizards (e.g., the Plio-Pleistocene locality Bad Deutsch-Altenburg, see in Rauscher 1992), shares a combination of features that only rarely occur elsewhere in Lacertini and is sometimes restricted to the two genera. The group of green lizards differs from *Timon* in smaller adult body sizes (Arnold et al. 2007). The frontal of the extant *Timon lepidus* can be distinguished from the *Lacerta* group *L. viridis* in the different proportion of the anterior and the posterior frontal portion (Fig. 3). However, this difference has previously not been observed and is also not discussed in Rauscher (1992). According to my comparison with six specimens of the extant *T. lepidus*, it is not a variable feature. The parietal is preserved only as a fragment of its posterior right portion of the bone. The sculpturing is identical to that in the frontals. These finds from early Miocene of the locality Dolnice near Cheb represent the earliest known occurrence of the European green lizards. The material is also clearly different from other extant European taxa of lacertids.

### Acknowledgements

I am indebted to D.S. Berman (Carnegie Museum of Natural History) and K. Smith (Forschungsinstitut Senckenberg Frankfurt) for their helpful advices. My thanks belong also to J. Klembara (Comenius University in Bratislava) for the opportunity to study the material described in this paper and to the National Museum in Prague for the opportunity to study material of Recent specimens. This paper was written with the support of the APVV Company, G. No. 0280-07.

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Received September 9, 2009

Accepted March 15, 2010