

## No gap in the Middle Permian record of terrestrial vertebrates

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In his comment, Lucas (2013) reiterates his earlier view that there was a marked gap in the tetrapod fossil record spanning the Roadian and Wordian of the Middle Permian, which I, and others (Reisz and Laurin 2001, 2002), have opposed. His arguments are far from certain, however. He says that the uppermost tetrapod-bearing terrestrial Permian beds in Oklahoma and Texas (United States) are Early Permian in age, and that the oldest Russian tetrapod-bearing beds are post-Roadian, so leaving a temporal gap of 2–3 m.y. On the first point, his view is not accepted by the majority of researchers, although the biostratigraphic evidence is far from watertight, and on the second, he is opposed by the majority of experts.

Lucas argues first that the youngest Permian tetrapod-fossil-bearing intervals of the Chickasha, Flowerpot, and San Angelo Formations in Texas and Oklahoma are Early Permian in age because the overlying marine Blaine Formation contains Early Permian (late Leonardian) ammonites. He argues also that the San Angelo Formation contains late Leonardian fusulinids. Despite the confident assertion, however, these ages are far from uncontroversial (e.g., Reisz and Laurin, 2001, 2002). For example, the ammonoids and other cephalopods in the Blaine Formation are found also in the Road Canyon and Word Formations in the Glass Mountains, the Cherry Canyon Formation in the Guadalupe Mountains, and the Delaware Mountain Group in the Delaware Mountains; hence, Roadian and Wordian (Middle Permian; DiMichele et al., 2004). Lucas's points about the age of the uppermost tetrapod-bearing units in North America were already refuted by Reisz and Laurin (2001, 2002), and the Middle Permian age is accepted in recent geological accounts (e.g., Sweet et al., 2012). The San Angelo Formation could indeed be latest Early Permian to earliest Middle Permian.

More controversial is Lucas' (2004, 2013) claim that the basal Russian Permian tetrapod-bearing units are late Roadian in age, whereas others have equated the Golyusherma tetrapod faunal complex with the late Kungurian and most of the Roadian, being partly Ufimian (e.g., Reisz and Laurin, 2001, 2002). There are three issues here: the age of the Ufimian, the age of the Golyusherma, and whether indeed the Golyusherma represents the oldest Russian tetrapod assemblage. The first point is widely accepted, in that the Ufimian is dated as upper Kungurian, and hence placed at the top of the Lower Permian on the basis of biostratigraphic evidence from foraminifera, ammonoids, bivalves, brachiopods, ostracodes, conodonts, insects, fishes, tetrapods, macroplants, and palynomorphs (Lozovsky et al., 2009). This is embedded in successive revisions of the international geological dating standard (Gradstein et al., 2004, 2012). Further, in these standards, and in various definitive Russian works (e.g., Leonova, 2007; Leven and Bogoslovskaya, 2006), the succeeding Kazanian stage is equated more or less precisely with the American, and international, Roadian stage in totality, not merely upper Roadian.

On the second point, equating the Golyusherma assemblage, occurring in a terrestrial, redbed succession, with marine stages is difficult, but Russian stratigraphers have always regarded the lower tens of meters of red sandy clayey rocks as Ufimian, and the remainder as lower Kazanian (Golubev, 1995, 2000). The Kazanian spans the entire Roadian, and the Baitugansk beds (not "Baitugen") referred to by Lucas are lowest Kazanian and correlative with the basal Roadian beds of the western United States

based on similarity between Pa elements of the conodont *Kamagnathus* and some Pa elements of *Sweetina triticum* from the Dry Bread Hollow site in Utah (Chernykh and Silant'ev, 2004; Leven and Bogoslovskaya, 2006).

On the third point, in fact, the Golyusherma tetrapod assemblage is not the oldest in the Russian Permian succession (Golubev, 1995, 2000). First is the Inta, dated wholly as Ufimian (i.e., Early Permian), then the Golyusherma, dated as late Ufimian to Roadian.

Hence, the Russian Permian tetrapod faunas span down to the Ufimian (= Kungurian), with the Inta assemblage, and the succeeding Golyusherma assemblage may also include some late Ufimian elements, but certainly spans the entire Roadian to the base, on the evidence of current Russian and international stratigraphic consensus. Therefore, "Olson's Gap" does not exist, whether the top of the North American Lower Permian redbed sequence enters the Roadian or not.

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