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We need a new GSSP for the base of the Jurassic System

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Since 1961, the IUGS International Commission on Stratigraphy (ICS) has been developing and standardizing the chronostratigraphic scale by defining chronostratigraphic boundaries by identifying Global Stratotype Sections and Points (GSSPs). To achieve this, the chronostratigraphic divisions of each geological system are being developed by a Subcommission, and each subcommission creates working (or task) groups to identify candidate sections and criteria for the selection of GSSPs defining the bases of relevant stage units.

In 1984, the Jurassic Subcommission created a working group to find a GSSP for the base of the Hettangian Stage, which is the lowest Stage of the Jurassic, though efforts to define a Jurassic base had begun in the 1960s (Maubeuge, 1964). After about 30 years of deliberation, the working group had identified four GSSP candidates: (1) St. Audries Bay, Somerset, UK; (2) Kennecott Point, Kunga Island, British Columbia, Canada; (3) New York Canyon area, Nevada, USA; and (4) the Utcabamba Valley, Peru (Fig. 1). It had long been known that a major turnover of the Ammonoidea characterizes the Triassic–Jurassic transition, so many workers favored an ammonoid signal to define the Jurassic base, though other signals, including radiolarian turnover and a carbon isotope excursion had their advocates (Fig. 2) (for a review, see Warrington *et al.*, 1994; Lucas *et al.*, 2007; Hillebrandt *et al.*, 2013).

In 2007, two new sections were added to the roster of potential GSSP candidates: Waterloo Bay, Northern Ireland, and Kuhjoch, Austria (Fig. 1). Furthermore, the group to vote on a GSSP was expanded to an unprecedented 75 members, 47 of them from Europe. The section at Waterloo Bay had been studied and published on since the 1800s, but nothing had been published on the newly discovered Kuhjoch section prior to its proposal by Hillebrandt *et al.* (2007) as a GSSP candidate (published in the ISJS Newsletter).

Despite this, the vote of the working group took place in February–April 2008, and the Kuhjoch section was chosen as the GSSP for the base of the Hettangian, and the Nevada section as an Auxiliary Stratotype Section and Point. The Jurassic Subcommission approved the decision in June 2008, the International Committee on Stratigraphy did so in May 2009 and, in April 2010, it was ratified by the Executive Committee of the IUGS. Hillebrandt *et al.* (2013) presented a detailed description of the Kuhjoch GSSP. Since its initial proposal, only one article (Hillebrandt, Krystyn, 2009) was published on the Kuhjoch section before it was ratified as the GSSP. Thus, the selection of Kuhjoch as the GSSP for the base of the Hettangian was added at the eleventh hour to a list of long studied and well understood candidates. Since nothing had been published on the Kuhjoch section prior to its proposal, its evaluation and discussion from the expanded group of voting members prior to its ratification was minimal.

Although the Kuhjoch section appears to contain a satisfactory paleontological and geochemical record, there are other aspects of the section that should have disqualified it from consideration as a GSSP. Palotai *et al.* (2017) recently restudied the Kuhjoch section, demonstrating that it is extensively disturbed tectonically – all the incompetent beds are foliated, there are tight to isoclinal folds in the strata and a reverse fault cuts through the GSSP section, so that part of the section is

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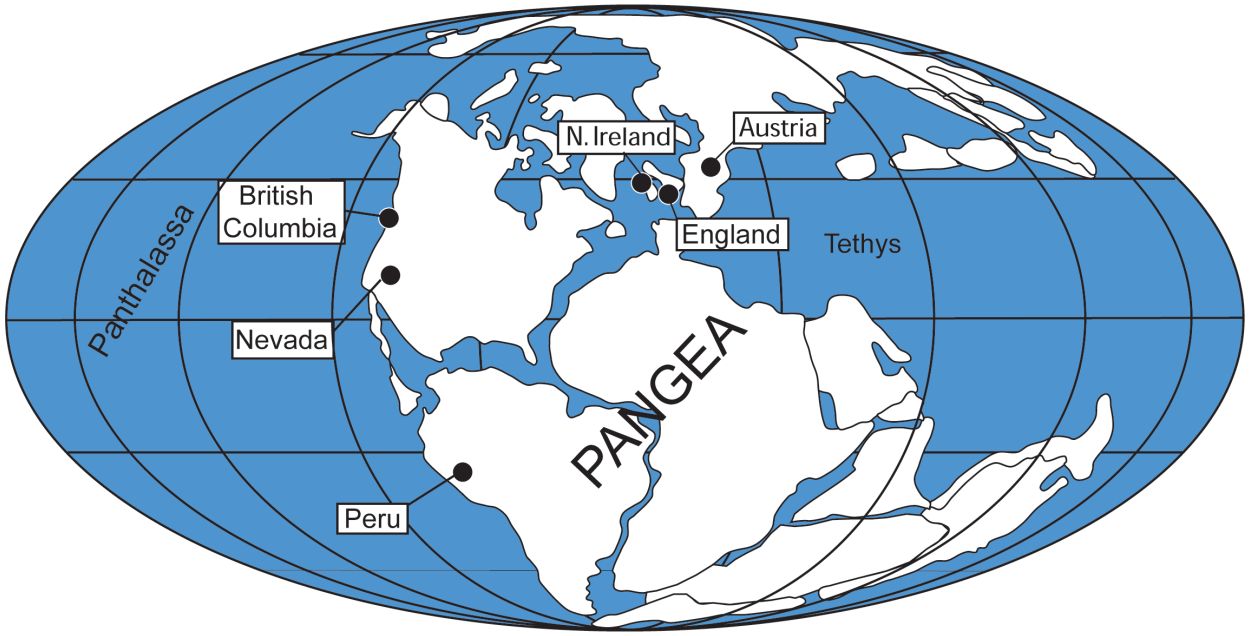

Fig. 1. GSSP candidates for the base Jurassic (Hettangian) GSSP voted on in 2008 (modified from Lucas *et al.*, 2007)

tectonically omitted. Hillebrandt *et al.* (2013, table 1) stated that at Kuhjoch there was "an absence of synsedimentary and tectonic disturbance near [the] boundary level". However, Palotai *et al.* (2017: 2475) concluded, "the Kuhjoch sections do not fulfill the specific requirement for a GSSP regarding the absence of tectonic disturbances near boundary level". Indeed, such tectonic disturbance of the section raises serious questions about the stratigraphic position and relationships of the biostratigraphic and chemostratigraphic events in the Kuhjoch section depicted by Hillebrandt *et al.* (2007, 2013). Additionally, the strata of the Kuhjoch sections are heavily weathered; sampling for paleontogical or geochemical analysis requires excavation with heavy equipment to expose fresh beds. Hence, each successive study examines slightly different rocks than previous studies (*e.g.*, Tanner *et al.*, 2016).

The choice of the Kuhjoch GSSP is a cautionary tale for those seeking GSSP-based chronostratigraphic definitions (also see Lucas, 2018). Typically, the process of choosing a GSSP takes at least a decade, as the relevant working group carefully evaluates and chooses a section that is very well understood and meets as many of the ICS criteria for a GSSP as possible. Furthermore, candidate sections are almost always sections that have been long known, long studied and have adequate published documentation. Kuhjoch was not such a section, and though it fell from the sky in 2007, it was also not a *deus ex machina*.

Clearly, a new GSSP for the base of the Jurassic is needed. The Jurassic Subcommission should create a new working group for that purpose. A possible solution could be to simply designate the auxiliary GSSP section in the New York Canyon area, Nevada, as the GSSP. That section continues to be the focus of much research (*e.g.*, Ritterbush *et al.*, 2014; Hodges, Stanley, 2015; Thibodeau *et al.*, 2016) and will serve as a GSSP without the tectonic complications that plague the current base-Hettangian GSSP at Kuhjoch, Austria.

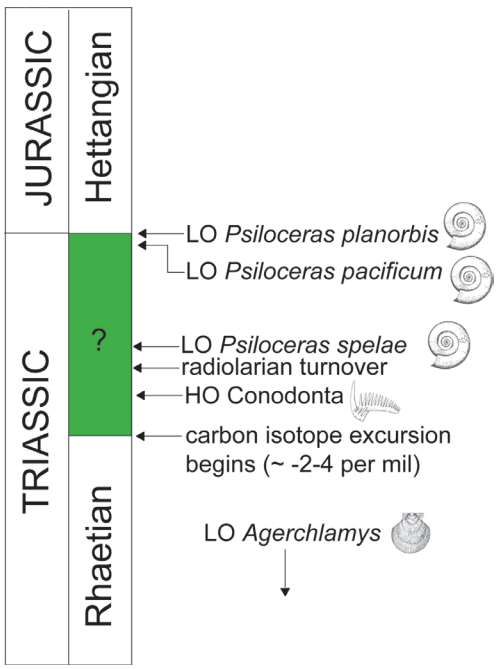

Fig. 2. Succession of potential primary signals for the base-Jurassic GSSP discussed and voted on in 2008 (modified from Lucas *et al.*, 2007). The green interval encompasses the range of most of the possible GSSP levels for the base of the Hettangian

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