# THE CHRONOLOGY OF THE PERMIAN AND TRIASSIC OF DEVON AND SOUTH-EAST CORNWALL (U.K.): A REVIEW OF METHODS AND RESULTS

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A combination of isotopic dating, biostratigraphy and magnetostratigraphy allows post-Variscan to pre-Jurassic formations in Devon and south-east Cornwall to be related to the international Permian and Triassic stages with varying degrees of precision. Isotopic dates from volcanic rocks in the lower part of the Exeter Group are Early Permian (Asselian to Artinskian) in age, consistent with the reverse polarities obtained from palaeomagnetic studies. The upper part of that group has yielded pollen that indicate a maximum age of Mid Permian (Roadian(?) or Wordian), and a few palaeomagnetic results, mostly with reverse polarity, that may suggest a pre-Illawara Reversal (pre-Capitanian) age. The magnetostratigraphy of the overlying Aylesbeare Mudstone Group indicates a post-Illawara Reversal (post-Wordian) age. That of the succeeding Sherwood Sandstone Group indicates ages ranging from late Olenekian (late Early Triassic), or older, in the lower part of the group, to early Mid Triassic (Anisian) in its upper part. The magnetostratigraphy of the overlying Mercia Mudstone Group indicates ages ranging from latest Anisian, in the lowest beds, through the late Mid Triassic (Ladinian) and early Late Triassic (Carnian), into the mid Late Triassic (Norian). The magnetostratigraphic evidence is compatible with macrofossil evidence of an Anisian age from the Otter Sandstone Formation, and palynological evidence of Carnian and younger Late Triassic ages from the Mercia Mudstone Group. The Penarth Group and basal Lias Group are Rhaetian (latest Triassic) in age, based on both bio- and magneto-stratigraphic evidence.

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## INTRODUCTION

The stage and series nomenclature currently used for the Triassic System was adopted by the Subcommission on Triassic Stratigraphy in 1992 (Baud, 1992); that used for the Permian System was adopted by the Subcommission on Permian Stratigraphy in 1996 (Jin Yu-gan *et al.*, 1997). A Global Stratotype Section and Point (GSSP) is required for the formal definition, in a basal boundary stratotype, of each stage. This process is incomplete; of the 17 boundaries involved, only eight have GSSPs ratified by the IUGS International Commission on Stratigraphy (ICS) (Table 1).

Ages have been assigned to all the stage boundaries (Table 1) but the geochronological control on this presently incompletely defined chronostratigraphy is imperfect. Satisfactory dates (e.g. U-Pb SHRIMP, TIMS or IDTMS dates from zircons from biostratigraphically well-controlled tuffs) are only available from levels in the highest Gzhelian to middle Asselian, upper Sakmarian, upper Wordian, middle Changhsingian to lower Induan, middle to upper Anisian, upper Ladinian and upper Rhaetian successions (Menning, 2001; Ogg, 2004; Wardlaw *et al.*, 2004); other levels are poorly constrained.

## THE SUCCESSION

The succession under consideration rests unconformably upon Devonian and Carboniferous rocks that were affected by the Variscan orogeny. It includes formations that constitute, in ascending order, the Exeter, Aylesbeare Mudstone, Sherwood Sandstone, Mercia Mudstone and Penarth groups, and the basal beds of the Lias Group (Warrington, 2004). This post-Variscan – pre-Jurassic succession is exposed in almost continuous sections on the south-east Devon coast, from Torbay to near Lyme Regis. The outcrop strikes northwards from the coast, through east Devon, into Somerset. Formations of the Exeter Group form a major westward extension of this outcrop in the Crediton Trough, with outliers farther west, and a smaller westward extension around Tiverton, bordered to the north by outliers. Isolated outliers of rocks of Exeter Group aspect occur at Portledge and Peppercombe in north Devon, at Slapton and Thurlestone in south Devon, and on the nearby Rame Peninsula in south-east Cornwall.

The means available for relating these deposits to the international chronostratigraphic scheme (Table 1) include isotopic dating, biostratigraphy and magnetostratigraphy. Only magnetostratigraphy (Opdyke and Channell, 1996) is potentially applicable to the complete succession; the application of isotopic dating is restricted to Permian formations with interbedded volcanic rocks, and that of biostratigraphy largely to formations of Triassic age. Macrofossils and trace fossils have been known from various levels in the succession for nearly 200 years, and microfossils and palynomorphs within the last 55 and 35 years respectively, mainly from Triassic formations. Palaeomagnetic work began in the early 1950's but magnetostratigraphic studies commenced only within the last ten years. Isotopic dating of volcanic rocks in the succession commenced about 45 years ago.

## METHODS AND RESULTS

### *Isotopic dating*

The possibility of using the amounts of the decay products of radioactive minerals to determine the age of the mineral was first clearly suggested by Rutherford in 1905 (Wager, 1964). In the succession under review its application is limited to the Exeter Volcanic Rocks. These are predominantly basaltic and lamprophyric lavas interbedded with continental deposits in the lower part of the Exeter Group around Exeter, in the Crediton Trough, and around Tiverton. Acid lava, though common as clasts in breccias, is rarely seen *in situ*; rhyolite occurs at Neopardy, in the Crediton Trough (Edwards and Scrivener, 1999), and in three small outliers on the Rame Peninsula, south-east Cornwall (Leveridge *et al.*, 2002).