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Post-Variscan Verrucano-like deposits in Italy, and the onset of the alpine tectono-sedimentary cycle

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ABSTRACT

In the Italian regions the stratigraphic successions of the Verrucano *s.l.* consist essentially of continental alluvial plain to coastal-neritic siliciclastic redbeds, deposited at different times in the Alps (Mid? –Late Permian), the Northern Apennines (Mid?–Late Triassic *p.p.*, locally in Southern Tuscany also followed by the Jurassic Pseudoverrucano Complex) and the 'Calabro-Peloritani Arc' (Mid?-Late Triassic, exceptionally reaching earliest Jurassic), whereas in Sardinia the recognition of the Verrucano succession is still a topic of discussion.

The most typical metamorphic lithofacies, in the Pisan Mts. of Tuscany, is represented by the Verrucano *s.s.* conglomerates and breccias, including quartz clasts and minor metamorphic and volcanic lithics, grading laterally and vertically to quartzitic sandstones and pelites.

In the Pisa Symposium the term 'Verrucano' was suggested only for those detrital deposits laid down, in the Alpine-Mediterranean areas, after the final act of the Variscan orogeny, and also to use local geographical names. Consequently, the typical terms 'Verrucano Toscano', the 'Verrucano Lombardo', the 'Verrucano Briançonnais' and other similar deposits, being linked to the Variscan belt, were generally accepted.

The ages of these 'Verrucanos', since they are devoid of fossils, can only be interpreted indirectly. The Verrucano Lombardo of central Southern Alps was recently ascribed to a Mid? –Late Permian interval (Late Guadalupian?–Lopingian *p.p.*), taking into account that the connected Val Gardena Sandstones of the nearby Venetian region are interdigitated with the Late Permian Bellerophon Fm. The Verrucano Briançonnais of the Maritime Alps is again mostly related to Late Permian, being covered by the Lower Triassic alluvial-deltaic quartzites. In the easternmost Ligurian Apennines, near La Spezia, the Mesozoic section of Punta Bianca, which begins with a fluvial conglomerate, transgressive and unconformable on a metamorphosed Paleozoic Variscan Basement, is composed of two main cycles, of which the upper one correlates to the typical Pisan Verrucano *s.s.* and the overlying Mt. Serra Quartzites, the latter yielding Carnian pelecypods and vertebrate footprints.

The Verrucano from the Mid-Tuscan Ridge to Mt. Leoni and in the Argentario promontory is delimited above by the Tocchi Formation and presumably developed from Middle (Late? Ladinian) up to Late Triassic (Carnian) times; in contrast, in Calabria (*e.g.* the Longobucco unit of Sila Grande) and in Sicily (*e.g.* the Taormina-Longi Unit of Peloritani Mts.) the so-called (Pseudo-) Verrucano deposits pertain to Mid? –Late Triassic and are capped by a basal Jurassic succession, determined by the discovery of an Early Hettangian palynoflora.

All over their distribution areas, the above-mentioned Alpine Verrucanos rest, through an unconformity marked by a gap of varying and imprecise duration, on Late Paleozoic volcanic/sedimentary successions or directly on the underlying Variscan metamorphic basement.

Schematically, the post-Variscan succession in Italy can be subdivided into three main tectono-sedimentary megacycles: the first generally ranges from the Late Carboniferous to, or slightly above the Early Permian, the second from Mid? –Late Permian to Middle Triassic, while the third cycle begins with the Mid?-Late Triassic *p.p.*, attaining the Jurassic in some parts of Southern Tuscany and the 'Calabro-Peloritani Arc'.

After the Late Carboniferous and Early Permian transtensional tectonics represented by many strike-slip continental basins (cycle I), widespread Middle Permian geodynamic reorganization ('Mid-Permian Episode' *Auctt.*) led to the development of a dominant extensional regime, and the birth of tectonic plates and oceans (Neotethys, Meliata-Maliak, etc.) between Africa and Europe. The erosion of the Variscan relief was followed by ingression from S-E sectors of shallow-marine branches of Neotethys (cycle II). The major rifting events that led

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to the Jurassic birth of the Ligurian-Piedmont Ocean started during the Middle–Late Triassic, and were related to the eastern opening of the Atlantic Ocean. These rifting events gave rise to the development of the Adria and Europe-Corsica-Sardinia conjugate passive margins, characterized by an asymmetric structural and sedimentary evolution. In this geological context, the Verrucano-like deposits of Italy can be interpreted as a discontinuous and asynchronous 'tectofacies' that marks the final dismantling of the SE border of the Variscan chain.

1. Introduction

The transition between Variscan orogenesis and the Mesozoic rifting that led to the opening of the Ligurian-Piedmont Ocean, and to the separation of the Adria and European plates, is even now not fully understood. In particular, the Late Paleozoic–Early/Middle Triassic tectonic setting of the southern margin of the Variscan chain has been interpreted as linked to three principal and contrasting geodynamic regimes: (a) the onset of a rifting process that continued until the Jurassic crustal break-up and oceanic spreading of the Alpine Ligurian-Piedmont Ocean; (b) a back-arc extension induced by the oblique subduction of the Paleotethys ocean beneath the southeastern margin of the Pangea continent; (c) an initial strike-slip to transtensional shearing affecting the southern side of the Variscan orogen between Eurasia and Gondwana, which was followed by a period of progressive extension until the Alpine rifting that began during Carnian–Norian times.

The aim of this paper is to examine the post-Variscan stratigraphic succession in Italy, and in particular the Verrucano-like deposits, in order to better clarify the geodynamic and paleogeographic evolution of this time interval (Fig. 1).

The term Verrucano, which was used for the first time by Savi (1832) in Tuscany, is generally ascribed in Italy to some peculiar, prevalent, fluvial to alluvial plain clastic deposits, cropping out in the Alpine and Apennine chains, as well as in Calabria and Sicily, and irregularly laid down during Permian, Triassic and also Jurassic times. The most characteristic lithofacies, in the Mts. Pisani type locality (NW Tuscany), is represented by Middle and Late Triassic mostly continental polychromous conglomerates and breccias. However, in this area, as in many other parts of the peninsula, the Verrucano shows frequently lateral and vertical variations into clastic sediments of smaller grain-size (sandstones-pelites), so that there is often great difficulty in defining its lithostratigraphical features. As an example, in the South-Alpine Permian, the lateral boundary between the Verrucano unit (to the west of the Adige Valley) and the Val Gardena Sandstone (to the east), which is well-developed in the Dolomites, raises a lot of problems because of the very gradual geometric interconnections of these two more or less coeval formations.

These lithological differences, which are often accompanied by colour, thickness and age variations, suggested, in accordance with the innovatory Symposium of Pisa, the assignment of the term 'Verrucano' only to those successions generally deposited in the Alpine-Mediterranean regions, after the final stages of the Variscan orogeny.

In this geological framework, according to the definition suggested by Trümpy (1966), in Mediterranean Europe the term Verrucano is suitable for indicating some lithostratigraphic formations deposited in an oxidizing environment (red and violet being the predominant colour), which represent intermittently the final dismantling product of the Variscan diastrophism and its subsequent post-orogenic cover.

In addition, Trümpy (1966) pointed out that the pre-Late Permian Verrucano deposits infilled basins and intramontane troughs, while the younger (generically Mid? –Late Permian to Triassic in age) deposited over widespread surfaces and are more similar to the Pisan Verrucano of the type locality. It is also recommended by the same author to distinguish them by geographical references (such as, *e.g.*, the Verrucano Lombardo, the Verrucano Briançonnais and, outside Italy, the Glarus Verrucano of the Swiss Alps), because of their generally evident diachronism and varying features from place to place.

As a consequence, the purpose of this paper is to provide a better understanding of the Late Paleozoic to Early Mesozoic stratigraphic architecture and tectono-sedimentary evolution recorded in some selected Italian areas. In particular, although the Verrucano-like formations still require new efforts for an exhaustive geological framework at a regional scale, this work focuses on their geodynamic and paleogeographical settings.

2. Regional stratigraphic review

2.1. Southern Alps

The Late Paleozoic continental successions of the Southern Alps (Fig.2) are characterized by two main and well differentiated tectono-sedimentary cycles, separated by a Mid–Permian regional unconformity which represents a time interval of about 20 Ma (Cassinis et al., 2012 and references therein).

The first cycle, with a maximum thickness of about 2 km, consists of alluvial-to-lacustrine sediments and calc-alkaline, acidic-to-intermediate volcanic products infilling fault-bounded intracontinental basins, interpreted as strike-slip or pull-apart basins, due to a transcurrent regime (Cassinis and Perotti, 1994). Paleontological evidence and isotopic data have established that this lower cycle ranges generally from the Middle Carboniferous (Moscovian/Westphalian) to the Early Permian (Kungurian or slightly above). Also in this lower cycle, and in particular in the well-investigated typical Collio Basin (Brescia province), a lithological unit similar to Verrucano formation (Dosso dei Galli Conglomerate: Cassinis, 1969; Cassinis and Peyronel-Pagliani, 1976) is present. This lithosome is characterized by a reddish massive succession lacking in fossils, up to a maximum of about 500 metres or more in thickness, which crops out only from the Camonica to Lower Giudicarie valleys.

The Dosso dei Galli Conglomerate mainly consists of metamorphic, quartz-vein and intra- and extra-basin volcanic lithoclasts, transported by mass-flow or debris-flow mechanisms that can be interpreted as a complex of amalgamated and irregular alluvial fan bodies prograding into, and sealing discontinuously, the Collio Basin (Cassinis and Perotti, 2007b).

Moreover, the above formation is widely crossed, almost from the base to its top, by a thinly bedded and dark red sandy-silty stratigraphic unit, rich in bioturbated structures (*Paleophycus tubularis*, *Planolites montanus*). This is known geologically as the 'Pietra Simona Member' and was deposited in low-energy transitional conditions (Ori et al., 1988; Ronchi, 2008). These layers locally also exhibit cineritic levels.

The Dosso dei Galli Fm. is overlapped by the violet Auccia Volcanite, which represents a last Permian calc-alkaline rhyolitic/rhyodacitic ignimbrite episode, up to about 100 m thick. Cassinis considered the Dosso dei Galli Conglomerate as an independent formation, separated from the overlying Verrucano *s.s.* Moreover, the 'Conglomerate' infilled intramontane subsiding basins, while the younger Verrucano Lombardo began from a very pronounced interregional unconformity on a progressively flat landscape.

Due to radiometric investigations by Schaltegger and Brack (2007), this Alpine clastic wedge is found to be pre-Middle Permian in age, generally dated to Cisuralian (Artinskian) times.

The first cycle was interrupted, due to erosion and/or non-deposition, by a geological event (the so-called 'Mid-Permian Episode': Deroin and Bonin, 2003; Cassinis et al., 2012), which probably involved the whole of southern Europe, indicating a plate reorganization and the