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RELATIVE TIMING OF EMPLACEMENT OF THE TUSCAN NAPPE ON THE APUANE ALPS METAMORPHIC COMPLEX

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In the modern geological literature, the Apuane Alps are considered to represent an example of a classical metamorphic core complex, with a dome shaped greenschist metamorphic core that is covered by the non metamorphic Tuscan Nappe (e.g., CARMIGNANI & KLIGFIELD, 1990). Isoclinal folding of the metamorphic core and emplacement of the Tuscan Nappe, is thought to have taken place in the Oligocene during collision of the Corsica-Sardina micro plate in the west with the Adrian plate in the East. Extension, responsible for refolding and exhumation of the metamorphic core, and renewed but extensional thrust motions of the Tuscan Nappe over the metamorphic core is thought to have taken place in the Miocene, the latter finally leading in the Pliocene to the development of major N-S trending horst-graben structures associated with opening of the Tyrrhenian sea. Following this scenario, the Tuscan Nappe was thrusted twice over the metamorphic core, first in the Oligocene, during the compressional event, and then back, in the Miocene, during the extensional event. The contact over which this multiple thrusting must have taken place, consists of a 1 to 100 m thick layer of breccia, thought to represent cataclastically deformed Triassic evaporites (the Calcare Cavernoso Formation). This breccia is characterised by clasts that originate from all types of metamorphic rocks that crop out in the Apuane Alps, and also from almost all types of non-metamorphic rocks of the Tuscan Nappe. According to CARMIGNANI & KLIGFIELD (1990) it is a huge extensional detachment fault.

We went to the Apuane Alps and studied the breccia near the villages of Monzone and Vagli (see Fig. 1), and found, astonishingly enough, conglomerates interbedded in the breccia. The pebbles seemed to originate from the metamorphic core as well as from the

Tuscan Nappe and were not brecciated. We also found that the (non-metamorphic) matrix looked like undisturbed sedimentary rock. The breccia therefore seemed to us of sedimentary rather than tectonic origin. We then found in the Italian geological literature, that others, notably DALLAN NARDI & NARDI (1973), DALLAN NARDI (1979), SANI (1985), ABBATE & BRUNI (1987), and COLI (1989) had already argued, that the breccia are of sedimentary origin. According to SANI (1985) they are deposited as marine debris flows in the Miocene (Langhian or younger according to DALLAN NARDI, 1979). These authors also found conglomerates interbedded, and even microfossils in the matrix. Now if the breccia are of a sedimentary origin indeed, then the metamorphic core of the Apuane Alps must already have been exhumed and exposed to erosion in the Miocene, and the Tuscan Nappe can only have thrusted over it after the erosion, in the Miocene or later (in the Tortonian according to COLI, 1989). This is in conflict with the view of the Apuane Alps as a core complex in the classical sense as advocated by CARMIGNANI & KLIGFIELD (1990) where the Tuscan Nappe must have overthrusted over the Apuane Alps in the Oligocene, prior to erosion and to exhumation. A sedimentary origin of the breccia would further suggest that the Oligocene age ductile compressional deformation of the metamorphic core is unrelated to the Miocene or younger overthrusting of the Tuscan Nappe. It also suggests that the exhumation and erosion of the metamorphic rocks (in the Miocene) is unrelated to the horst-graben formation and opening of the Tyrrhenian Sea (in the Pliocene).

The main argument of CARMIGNANI & KLIGFIELD (1990) that the breccia are of tectonic origin is that according to them they are not only present as a flat lying dome-shaped cover over the entire metamorphic core, but locally also as lenses in the cores of tight synclines *in* the metamorphic core. Because these synclines developed during the Oligocene compressional ductile deformation phase, the breccia plus the Tuscan Nappe must already have lain on the metamorphic core in the Oligocene before ductile deformation and folding of the metamorphic core could have taken place.

We had a detailed look at a few locations where according to CARMIGNANI *et al.* (1978) and CARMIGNANI & KLIGFIELD (1990) such tight synclines are exposed, namely in the area around Vagli (see Fig. 1). An examination of the site revealed, however, that it is not at all immediately evident, that there is question of tight synclines. The interpretation as tight synclines is very speculative due to the quality of the outcrops. But there are further problems:

(i) The breccia look undeformed and show no peneterative deformation features. This is very strange. If they were tightly folded in

the Oligocene they should have shown intense deformation features as all of the other rocks deformed in the Oligocene.

(ii) The matrix of the breccia is nowhere metamorphous. If the breccia were tightly folded during the Oligocene deformation phase, then they should be metamorphosed to greenschist facies, just as the neighbour schist. But this did not happen. The breccia unmetamorphous and contains non-metamorphous clasts and pebbles.

(iii) Detailed examination of the contact of the breccia with the metamorphic rocks in the field near Vagli suggests that it is an unconformity. The unconformable nature of this contact is also apparent on the large scale, as can be clearly seen on CARMIGNANI's (1984) map.

According to us, the above observations are much better explained if the tight synclines of CARMIGNANI *et al.* (1978) actually represent Miocene age sedimentary breccia deposited in an Upper Miocene palaeorelief, just like the sedimentary breccia of Jurassic age that were mapped by COLI et al. (1992) in the area around Monte Sagro - Morlungo somewhat further north. In any case, the interpretation of the breccia as Oligocene age isoclinal folds seems highly questionable, and should therefore not be used as an argument that the Tuscan Nappe must already have lain on the Apuane Alps by Oligocene times. We therefore conclude that the Tuscan Nappe was emplaced on the Oligocene age metamorphic complex only after Miocene exhumation and erosion of the latter.

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Figure 1. Schematic map of the Apuane Alps after CARMIGNANI and KLIGFIELD (1990). 1: Non metamorphic Tuscan Nappe; 2: breccia; 3: metamorphic core;