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Northward subduction and the emplacement of the ophiolite belts of the Central Alps: a working hypothesis

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ABSTRACT

In current plate tectonic interpretations of the origin of the Central Alps a south-dipping subduction zone is preferred. However, a north-dipping subduction zone seems to explain consistently all geologic observations related to the origin of the Central Alps and is submitted here as a working hypothesis.

Introduction

Since the experiments of RALEIGH & PATERSON (1965) on dehydration weakening of serpentinite provided essential concepts, the mechanism of tectonic emplacement of Alpine-type ophiolite belts has received much attention (COLEMAN 1971; DEWEY & BIRD 1971; ERNST 1970, 1973*a*, 1975; GANSSER 1974; GASS et al. 1975; LOCKWOOD 1972; ROD 1974). The emplacement of the ophiolites is closely associated with blueschist metamorphism and the origin of the ophiolite mélange, and the occurrence of all those rock bodies is controlled by major geosutures.

The ophiolites represent lenses and slices sheared off from the oceanic crust and mantle. These slices were dragged into the subduction zone with the downgoing slab and were then uplifted along major shear zones from the depths of as much as 30 km. This process occurred at a time when the whole collision zone was being strongly compressed during a phase when the movements along the subduction zone ceased. In the final phase those ophiolite sheets and lenses were emplaced by gravity sliding.

As the ultramafic and mafic rocks of the ophiolites were generated at a spreading ridge and migrated as part of the sea floor towards the convergent plate boundary, it might have taken these ultramafic rocks, exposed in the ophiolite belt, some 20 m.y. to 100 m.y. from the time of their generation until they reached the zone of high-pressure/low-temperature metamorphism in the subduction zone (ERNST 1973*b*, 1975; ROD 1974). The phase of buoyant uplift may have lasted at least some 5 m.y. to 30 m.y.

A wealth of information on the Alpine orogenic belt is available and it is certainly not too early to apply the plate tectonic theory in trying to explain the

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origin of the Alps. But, there is always the danger that one idea, one only of several different ways to explain the genesis, will soon become fashionable. The possibility of such pitfalls is envisaged by ENGEL et al. (1975), who write: "We do hope that iteration and reiteration of a concept does not come to be equated with proof of its pervasive validity, however popular the concept may be."

In current plate tectonic interpretation of the origin of the Central Alps a south-dipping subduction zone is preferred (LAUBSCHER 1970; DEWEY & BIRD 1970; ERNST 1973*b*, 1975; GANSSER 1973; TRÜMPY 1975; TRÜMPY in BERNOULLI et al. 1974). A subduction zone dipping north and west is postulated by HSÜ & SCHLANGER (1971) for certain phases in the evolution of the Alps and by OXBURGH (1972), for certain processes of tectonic emplacement of crustal slabs.

As it seems, any direction of tectonic transport which does not fit a certain scheme is readily explained by a postulated flip of the subduction zone (HSÜ & SCHLANGER 1971; ROEDER 1973).

It should be obvious from the available literature that the vergence and direction of tectonic transport alone do not say much about the polarity of the subduction zone (ROEDER 1973).

The purpose here is to consider an alternative working hypothesis and to show that a north-dipping subduction zone can explain the geologic observations in the Central Alps. The proposed tectonic mechanism for the emplacement of the ophiolite belts in the Central Alps by the movements and deformations of a north-dipping subduction zone is shown diagrammatically in the sections of Figure 1.

Observations and assumptions

a) Ivrea Zone

In all considerations of the origin of the Central Alps, the Ivrea Zone is of fundamental importance (VECCHIA 1968) as is obvious from a study of the several excellent papers in the Symposium "Zone Ivrea-Verbano" (1968). This zone is an old continental crustal block containing the remnants of at least two Paleozoic orogenic belts (Hercynian and Caledonian) and likely also fragments of Precambrian ones. The much discussed ultramafic rocks of the Zone Ivrea-Verbano are portions of older ophiolite complexes (VUAGNAT 1968) belonging to one or several Paleozoic orogenies.

That such an old landmass should be cut through and through by fault zones is not astonishing. The Insubric Line, the major fracture zone bounding the Ivrea Zone to the northwest, is such a rejuvenated old fault zone (GANSSER 1968; GIRAUD 1968).

b) Insubric Line

The Insubric Line is a system of fault zones consisting of portions of some very old and some younger shears which were active at various times during their long history (for an excellent review, see GANSSER 1968).

After the Alpine main phase of deformation in early Oligocene time, the terrain along the west-east trending portions of this fault system was displaced by right

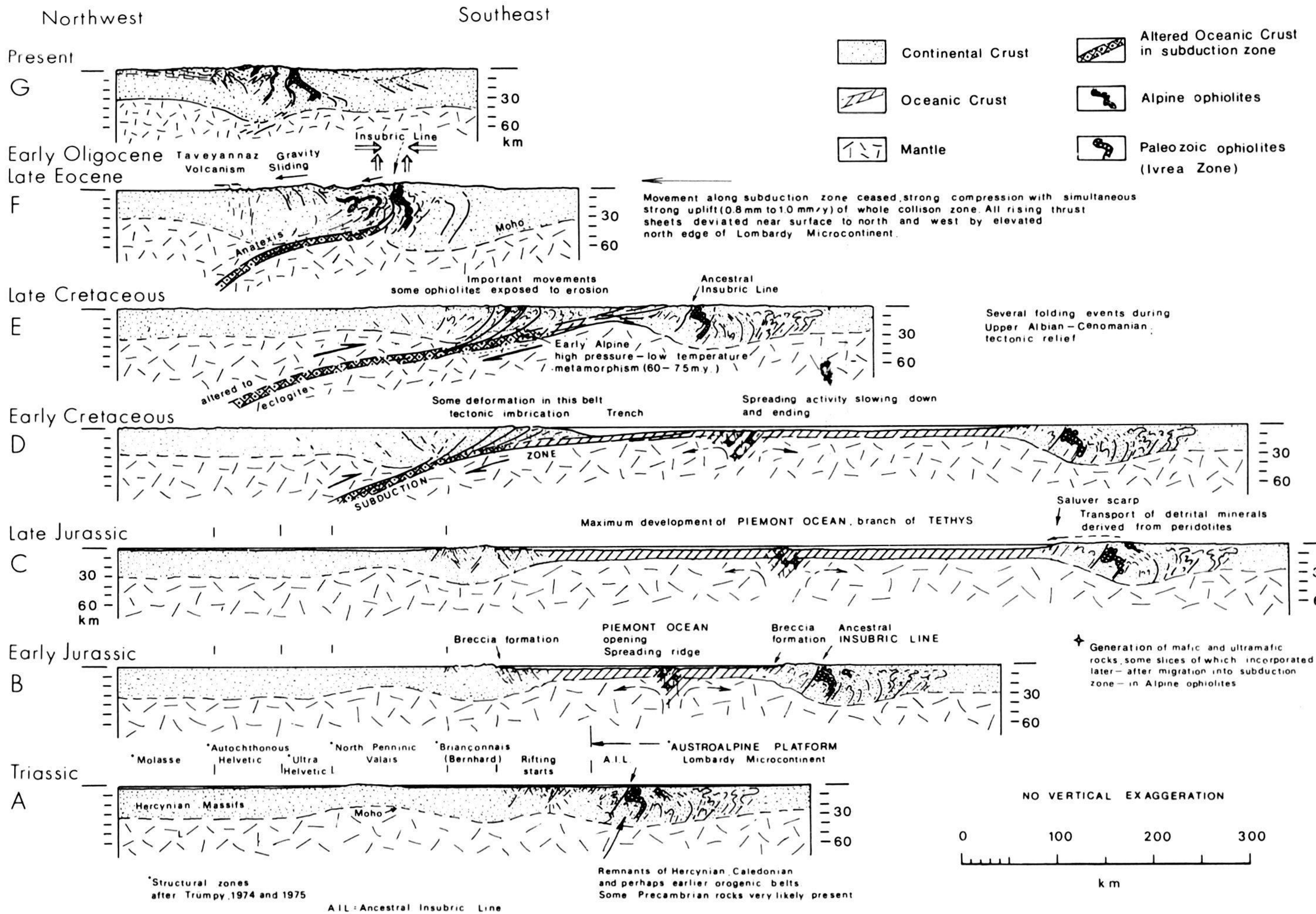

Fig. 1. Diagrammatic sections showing development of Central Alps. The line of section for all diagrams is the axis of a broad belt trending northwest-southeast, from the Jura Mountains at one end to the Po depression, southeast of the Ivrea Zone, at the other. This line passes through central Valais.

strike-slip movements (GANSSER 1968; LAUBSCHER 1970, 1971*a*, 1971*b;* TRÜMPY in BERNOULLI et al. 1974). As in most large-scale strike-slip faults, the apparent dip-slip component might be very large locally and might distract from observing the horizontal component which could easily be larger by a factor of ten.

Other portions of the Insubric Line, as for example the segment bounding the Zone Ivrea-Verbano on the north-west, appear to have all the characteristics of steeply dipping thrusts. This fault bounding the Zone Ivrea-Verbano seems to go back in its origin to the early Paleozoic or to the Precambrian. During the Hercynian and Caledonian orogenies it might have been one of the many imbricate faults at the leading edge of the continental plate. The main western branch of the Insubric Line seems to be the Simplon-Centovalli Fault and not the thrust fault bounding the Ivrea Zone.

c) Ophiolite complexes

Among the investigators of ophiolites it is standard practice to compare sections of oceanic crust and mantle with columnar sections of ophiolite complexes constructed from observations of outcrops. The thicknesses calculated from the restored ophiolite complexes might be reasonable, but it is certainly a serious mistake to conclude from the columnar sections that the ophiolite nappes or sheets have similar thicknesses. The ophiolite sheets are actually rarely more than 3 km thick and measure as an average less than 1 km. Any reports or illustrations indicating thicknesses of ophiolite nappes or sheets of over 5 km should be viewed with suspicion.

Why those ophiolite sheets are thin can easily be understood if it is realized - as shown in Figure 2 - that the oceanic crust and underlying upper mantle are cut by swarms of very gently dipping shear zones. Near the trench and in the subduction zone such shear zones may dip at an angle of about 6 degrees, inclined in the same direction as the subduction zone (HUSSONG et al. 1975).

The long migration of the rock bodies forming the ophiolite complexes from the locality of generation in the centre of the spreading ridge toward the trench and into

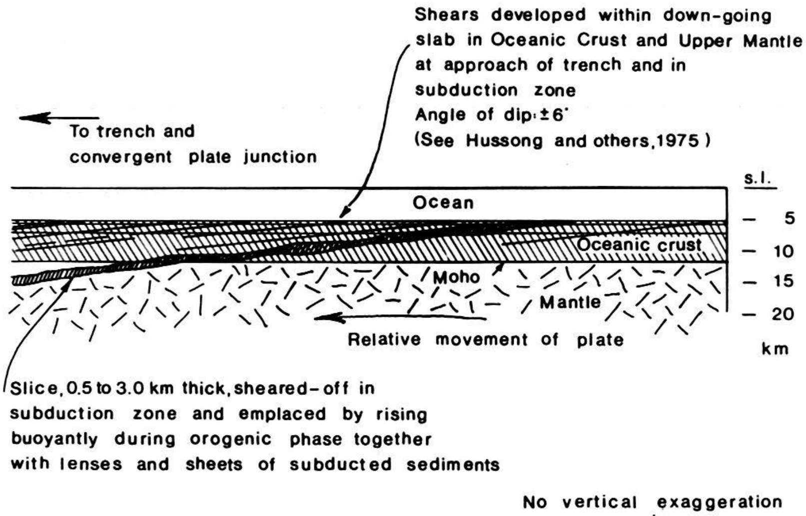

Fig. 2. Suggested mechanism for origin of ophiolite slices.

the subduction zone, is well documented by radiometric age determinations (ERNST 1973*a*, 1973*b*; JÄGER 1973).

d) Width of Piemont Basin

The maximum width reached by the Piemont Basin, before the floor was being consumed in the subduction zone along the northern and western rim of the basin, is still uncertain. On Figure 1C, a width of 580 km has been assumed. According to TRÜMPY (in BERNOULLI et al. 1974, and 1975) estimates vary between 100 and 750 km.

e) Igneous activity

Evidence for widespread andesitic volcanism in the Helvetic realm is provided by the volcanic debris in the late Eocene to early Oligocene Taveyannaz Sandstone (HSÜ & SCHLANGER 1971; TRÜMPY 1975). This is very likely the most significant clue for a north-dipping subduction zone. The andesitic volcanism occurred in a belt some 150 to 175 km north and west of the original convergent plate junction (Fig. 1F).

Although the constituents of the Taveyannaz Sandstone may locally consist of over 90 percent of debris derived from andesites and would thus indicate the nearness of the volcanoes to the basin of deposition, and inspite that this over 400 km long belt of Taveyannaz Sandstone deposition lies in a region of the Alps which might be considered as one of the most thoroughly explored part of our globe, no remnants of volcanoes, no vents, volcanic pipes or lava flows have been discovered until today.

MARTINI & VUAGNAT (1967) analysed in detail the several possible source areas for the large volume of volcanic debris in the Taveyannaz Sandstone and considered - among others - a working hypothesis whereby the volcanoes were located in the southern part of the Penninic zone. Moreover they postulated that during Taveyannaz Sandstone deposition the andesitic detritus came from the erosion of remnants of lava flows which had been incorporated in some advancing nappe.

However, as MARTINI & VUAGNAT (1967) pointed out and as was confirmed by SIEGENTHALER's observations (cited in TRÜMPY 1975) of volcanic bombs and lapilli, there is strong evidence that the volcanic belt was immediately south and southeast of the basin of deposition. It is therefore reasonable to assume that Taveyannaz volcanism and sedimentation were contemporaneous (TRÜMPY 1975).

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