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THE GEOMETRY OF STRUCTURES FORMING AROUND THE DUCTILE-BRITTLE TRANSITION IN THE VOURINOS-PINDOS-OTHRIS OCEANIC SLAB

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ΣΥΝΟΨΗ

Η μελέτη της δομής των οφιολιθικών συμπλεγμάτων Βούρινου, Οθρυος και Πίνδου έδειξε ότι οι δομές υψηλής θερμοκρασίας (ασθενοσφαιρικές) έχουν ανάλογη γεωμετρία με τις όλκιμες ωκεάνειες (λιθοσφαιρικές) και θραυσιγενείς δομές, που συνδέονται με την τοποθέτηση των οφιολίθων. Οι δομές υψηλής θερμοκρασίας έχουν περιστραφεί μέσω της όλκιμης παραμόρφωσης παράλληλα προς τη διεύθυνση τοποθέτησης. Τόσο η περιστροφή όσο και οι δομές που έχουν σχηματιστεί κοντά στο όριο όλκιμου/θραυσιγενούς συμβιβάζονται με κίνηση προς βορειοανατολικά. Η παραλληλία των όλκιμων/θραυσιγενών δομών στα τρία οφιολιθικά συμπλέγματα υποδηλώνει ότι αυτά αποτελούσαν κατά την αποκόλληση ενναιαία ωκεάνεια πλάκα.

ABSTRACT

Structural studies in the Vourinos, Othris, and Pindos ophiolites show a correspondence in geometry between high temperature peridotite fabrics (aesthenospheric), later ductile oceanic fabric (lithospheric) and brittle emplacement structures. High temperature fabrics are rotated through ductile deformation into an emplacement parallel orientation. Structural rotation and structures formed near the ductile-brittle boundary, reconcile verging towards the northeast. The parallelism of the three ophiolites at the ductile/brittle boundary suggests that they were part of a contiguous oceanic slab at the time of detachment.

INTRODUCTION

Conditions of peridotite deformation have been well-studied (e.g., Nicolas and Boudier, 1975; Nicolas and Poirier, 1976; Borley, 1976; Gueguen and Bouillier, 1976), such that the approximate thermal regime of any particular fabric can be estimated both from field observation and verified in petrographic examination. Some work of this kind has already been established for the Vourinos ophiolite (Ross and others, 1980; Frison, 1987), and has been analytically applied to ophiolites such as Oman (Nicolas, 1989). We are presently concluding an eight-year tectonic study of the Othris, Pindos, and Vourinos peridotites (figure 1) including differentiation of fabric type and geometry, and internal structural analyses. The peridotites of western Othris have been mapped at 1:50,000 scale (Rassios and Konstantopoulou,1992;1993 in prep.); about 800 km2 of the Pindos ophiolitic terrain is completed at 1:20,000 scale (Rassios and Grivas,

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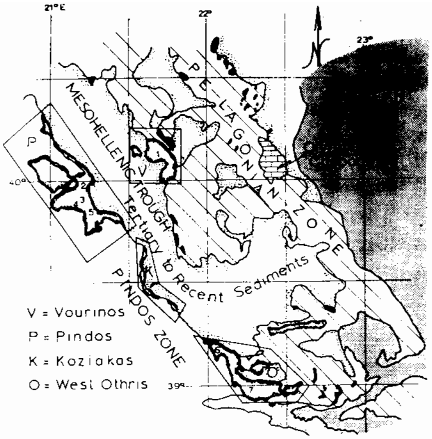

Fig.1: Location of the Vourinos (V), Pindos (P), Koziakas (K), and West Othris (O) Ophiolites. Specific localities: 1. Voidolakkos; 2. Dramala; 3. Salatoura; 4. Mavrovouni; 5. Koukourelo; 6. Smokovo; 7. Mega Isoma.

Σχ.1: Τοποθέτηση των οφιολιθικών συμπλεγμάτων Βούρινου(V), Πίνδου(P), Κόζιακα (K) και Δυτικής Οθρυς(O). Ειδικές τοποθεσίες: 1. Βοϊδόλακκας, 2. Ντραμάλα, 3. Σαλατούρα, 4. Μαυροβούνι, 5. Κουκουρέλο, 6. Σμόκοβο, 7. Μέγα Ισωμα.

1992; and 1993 in prep.), and Vourinos as a whole and by mine district on scales of 1:10,000 down to 1:1000 (Konstantopoulou, 1992a, 1992b, 1990; Konstantopoulou and Wright, 1990; Grivas and others, 1993; Roberts and others, 1988; Wright, 1986, Grivas and others, 1986). This paper deals with aspects of peridotite deformation within the three ophiolites accompanying the ductile-brittle transition.

An ophiolitic slab is assumed to be at high temperatures of about 1250 degrees near the spreading centre, and cool gradually as it moves into cooler temperature regimes accompanying slab detachment and obduction. A. Nicolas (1989) deems high temperature fabrics (about 1200 C) as aesthenospheric, and those formed below 1000 degrees as lithospheric in origin; peridotites deform in brittle fashion at temperatures below about 700 degrees (Calmant, 1987, Watts and others, 1980). The following basic assumptions are made concerning the period of lithospheric deformation (Grivas and others, 1993):

a. The slab ranges from relatively high temperature and pressure conditions (ductile field) at its base to cooler brittle field conditions at its top. Thus, at any time in its history, brittle structures form in the same strain framework as concurrent ductile structures lower in the slab.

b. The ductile to brittle boundary is assumed to be shallow near the ridgecrest and to deepen with distance from it. Thus, lower temperature deformation penetrates to deeper levels and imprints higher temperature structures with the lower geotherm approaching the continental margin.

c. During obduction, an ophiolitic slab is transported from oceanic to continental conditions via constriction and thrusting. Concurrent ductile and brittle structures from this period share the same strain environment.

Detachment of the slab itself is a brittle deformation, and temperatures of ophiolitic amphibolite soles are about those of the cessation of ductile deformation of peridotite (Ghent and Stout, 1981; Spray, 1984; Zimmerman, 1968). Ductile deformation in the Oman ophiolite apparently terminated preceding establishment of detachment strain (Nicolas, 1989), such that oceanic regime structures can be considered separately from those of detachment and emplacement (that is, the obduction overprint is entirely brittle field and independent of oceanic strain). For the ophiolites of our study, mylonitic (lithospheric) ductile deformation concurs in geometry with that of emplacement tectonism; this implies (at least in the case of Vourinos, the Pindos, and Othris) that detachment was preceded by a ductile phase of deformation which effectively turned older, hotter structures into the emplacement geometry, and strained the slab towards the obduction front immediately preceding brittle detachment.

Our structural studies are based on the point of view of the ophiolitic peridotites of Vourinos, Othris, and the Pindos: we are interested in strain recorded by the peridotite and less so with tectono-stratigraphic correlation. Only later brittle deformations to the peridotite can be correlated with structures in non-ophiolitic regional hosts (such as in flysch formations) or as structures cross-cutting both the ophiolitic and younger formations (such as faults relating to formation/closure of the Meso-Hellenic trough, Rassios and Grivas, 1992).

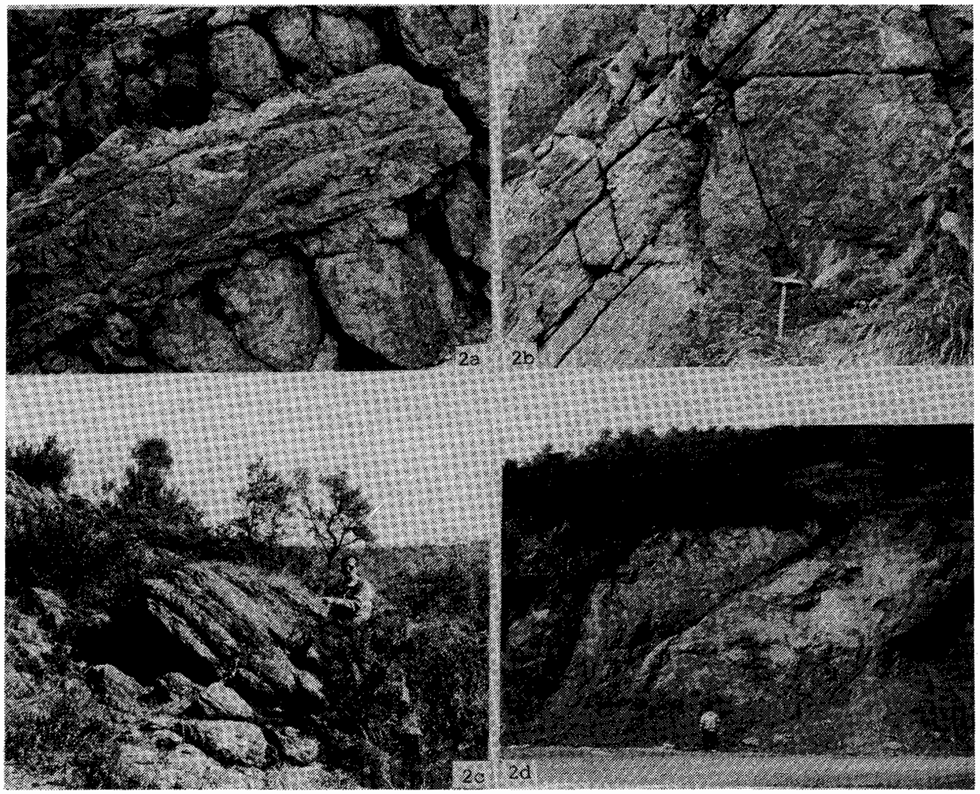

Fig.2. a: "Aesthenospheric" peridotite hosting "lithospheric" mylonite, zones, Voidolakkos, Vourinos ophiolite. b. Pervasive mylonitic "Lithospheric" peridotite. Note brittle shears parallel to fabric. c. Ductile-Brittle shears, Vourinos ophiolite. d. Brittle shears, tectonic imbricates, Othris ophiolite.

Σχ.2. α: "Ασθενοσφαιρικός περιδοτίτης που φιλοξενεί "λιθοσφαιρικές" ζώνες μυλονιτίωσης, Βοϊδόλακκας Βούρινου. β. Μυλονιτικός "λιθοσφαιρικός" περιδοτίτης. Οι θραυσιγενείς ζώνες ολίσθησης είναι παράλληλες προς το μυλονιτικό ιστό. γ. Ολκιμες/θραυσιγενείς ζώνες ολίσθησης, Βούρινο. δ. Θραυσιγενείς ολισθήσεις και λεπιώσεις, Οθρυς.

OPHIOLITIC STRUCTURES WITHIN PERIDOTITE

The earliest and highest temperature structures recorded by ophiolitic peridotites (aesthenospheric) reflect strain imposed on mantle rocks shortly after, and possibly concurrent, to partial melting. Ross and others (1980) estimate the conditions responsible for such deformation as 1200 to 900 C at 100 to 40 km depth for the Vourinos ophiolite. These structures tend to look like a weak mineral fabric in the field, since most deformation is effected by intra-crystalline ductile mechanisms and annealing; the rocks (figure 2a) are coarse-grained harzburgites and lherzolites with blocky pyroxenes: shape-defined foliations are somewhat difficult to discern in the field but petrofabric orientations are quite strong (Ross and others, op. cit.; Harkins and others, 1980; Jackson and others, 1975). In some areas, mantle compositional layering is apparent, a structure considered by Nicolas (1989) as due to relict aesthenospheric flow. These high-temperature structures may be used to determine the sub-ridgecrest strain framework as for Oman (Nicolas, op. cit.), or, as we propose herein, they may have been passively rotated by subsequent lower temperature movement, thus obscuring original ridgecrest geometry.

Mylonitic structures (figures 2a,b) are more diverse in type and in appearance. At temperatures of about 1000 down to 800 C, peridotite deforms under increased shear stress, and a strong shape-defined foliation is observable in the field. Mylonitic fabric can be pervasive over large areas (such as the Pindos Koukourelo Massif of about 10 km2) or restricted to discrete mylonite zones hosted by peridotite of higher temperature strain, such as the mylonite zones of Voidolakkos, Vourinos. Annealing of neoblasts in these conditions is greatly aided by the presence of fluids (Borley, 1976; Kurat, 1984, Nicolas and others, 1987; Norton, 1988); the presence of amphiboles has been observed in mylonitic samples from the Pindos and Vourinos, as well as large, undeformed euhedral spinels that appear to have undergone metasomatic growth into and along mylonitic foliation.

In the Dramala Massif of the Pindos (Rassios, 1987), a pervasive mylonitic fabric affects peridotites immediately above the basal sole and is presumed a result of sole formation and detachment as for similar mylonitic peridotite overlying the soles of other ophiolites (Nicolas, 1989). Elsewhere in the Dramala massif, zones of pervasive mylonitic material can reflect incipient detachment zones, broad zones of ductile faults, the ductile portions of faults that penetrate from brittle to ductile field, or areas of heterogeneous fluid presence in conditions of otherwise homogeneous stress.

Distinct mylonite zones best describe deformation within the ductile/ brittle transition itself. Mylonite zones cross higher-temperature aesthenospheric and lithospheric structures. The mylonite zones of Vourinos (Grivas and others, 1993) describe the transition precisely: mylonite zones of low-temperature ductile deformation cross higher-temperature fabric of regional harzburgite; these zones are continuous into dunite bodies where the zones become brittle shear zones. We thus conclude that while harzburgite is still undergoing ductile deformation within discrete mylonitic zones, dunite is deforming as a brittle material.

Ductile-brittle shears (figure 2c) display an appearance of both mylonitic and brittle fabric. Thin cataclasis zones, sometimes with growth of neoblast phases, accompanies a brittle fracture. Zones of such shears, as at Ano Konivos, mimic imbricate geometry.

Brittle shears can be arrayed in shear zones, ramping structures, or imposed upon older brittle structures (figures 2d). Relative ages of brittle systems are easily judged by the statistical interpretation of cross-cutting relations in outcrops including multiple shear sets. In the Mega Isoma area of Othris (Rassios and Konstantopoulou, 1992), for example, twenty-one outcrops could be so investigated: each included three distinct imprinting shear sets. Pindos peridotites contain two older shear systems overprinted by younger shears. Through relative dating, brittle shears of both the Pindos and Othris thus can be divided into three general strain sets: i) Old sets parallel emplacement deformation verging towards the northeast and, as we will show, parallel ductile deformation, ii) Intermediate sets require thrusting and verging to the southwest and probably correlate with Eocene movement of the peridotite massifs over flysch; iii) Young shears (of several deformational episodes) relate to local compressional neotectonics.

Studies of shear deformation in complex brittle fault zones (such as within duplex faults, e.g. Doutsos and Poulimenos, 1992), while greatly respected by ourselves, have not been analysed in detail by our group. Where possible, we examine structures around such faults to make estimates of relative movement. We would like to point out, however, that as for low-temperature faults, high temperature ductile zones may show evidence of contradictory strain (that is, constrictional in some parts, and extensional elsewhere). Relative movement across emplacement tear systems in peridotite thrust sheets is difficult to evaluate since distinct marker units are generally lacking (in rare cases, an offset dike or dunite contact can be found), and since these are in affect transform faults (peridotites on both sides of the fault are moving in the same direction, with one side moving more rapidly than the other), they deflect older fabrics into the fault zone by nearly mirror-image bowing of older fabric.

Parasitic deformation is a major consideration of complex structures in all three ophiolites. Obviously, once a weakness zone is established in the peridotite at any temperature, it provides a preexisting weakness for facilitating deformation at subsequently lower temperatures later in the history of the massif. In the Mavrovouni area of the Pindos, mylonitic fabric zones several hundreds of meters broad parallel and host ductile-brittle fault zones that facilitate emplacement tear motions; these systems initiate at temperature conditions on the order of 1000 degrees and thus date from an oceanic setting of the mantle slab. However, the brittle lineaments observed in aerial photographs accompanying these same structures can be traced as brittle faults into flysch formations (Migiros, unpubl. map); this is an excellent example of re-activation of oceanic faults in a much younger tectonic environment. In Othris, analyses of shears within tear systems show that the same faults which facilitated emplacement movement of ophiolitic nappes to the northeast are parasitically overprinted by later nappe-over-flysch thrusting to the southwest. Emplacement tear systems initiating in oceanic conditions provide a convenient breaking point for low temperature faults relating to movement of the nappes over the flysch in the opposite direction (Rassios and Konstantopoulou, 1992).

Such parasitic strain in the Pindos is chiefly responsible for the formation of northeast-southwest directed corridors which divide ophiolitic nappe units and complicate relations between ophiolitic and melange imbricates with flysch and limestone basement. Mechanically competent limestone in such a deforming zone in which the hosting material consists of relatively incompetent serpentine, melange matrix mudstones, and flysch, has a tendency to protrude through the corridors, becoming tectonically juxtaposed atop ophiolitic and melange units, i.e., forming resistant pop-up teeth and ridges. Away from the corridors, the strato-teconic succession of Jones and Robertson (1991) is always the rule.

THE GEOMETRY OF OPHIOLITIC FABRICS AND STRUCTURES FORMED NEAR THE DUCTILE-BRITTLE BOUNDARY

In the present review, we illustrate some of the structures and their effects on peridotite deforming in conditions near the ductile-brittle transition:

I. Structural Rotation of Fabric (Pindos)

The orientation and approximate thermal conditions of peridotite fabrics have been noted over the contiguous peridotite nappes of Dramala, Salatoura, and Mavrovouni. Field analysis of strain conditions (Rassios, 1987) have been backed up by petrofabric examination; in short, fabrics noted as type I during mapping as a weak orientation of blocky orthopyroxenes are aesthenospheric according to the definitions of Nicolas (1989); those of types II, III, and IV form at decreasing temperatures such that type IV peridotite is a pervasive mylonite with elongation ratios of remnant orthopyroxene in excess of 5:1 and represents the lithospheric end of such fabrics.

Figure 3 shows pi diagrams of planar fabrics representative of structures formed in decreasing thermal regimes of the peridotite. The transition in orientation between fabric types is continual. The earliest aesthenospheric fabric shows a maximum indicating southwest-dipping planes. These rotate into steep, southeast dipping planes via continuous ductile deformation at decreasing temperatures (stages II, III, IV). Mylonite zones (stage V) are strictly parallel to pervasive mylonitic fabric (stage IV). At the ductile-brittle boundary, ductile-brittle shears (triangles in stage VI) overlap geometrically with the preceding mylonitic deformation, and with oldest brittle shears (contoured distribution of stage VI) which show an orientation similar to *that of the highest temperature structures, stage I, above. The overprint of totally brittle shears reconciling cold-temperature thrusting towards the southeast is shown as stage VI. (Later neotectonic shears are deleted from the present summary.) We thus conclude (a) that high temperature fabrics are rotated to an orientation parallel to that of constrictional lithospheric strain, and (b) that oceanic lithospheric and early brittle constrictive strain are parallel.

II. Ductile imbricate structures

Within all three ophiolites of the present study, a particularly intriguing sets of drag or sheath folds have been discovered which mimic ramp structures. These folds are shaped like tongues and have wavelengths of tens to at most a hundred metres, and thus are difficult to map individually on all but the most detailed map scales (i.e., in excess of 1:1000 scale).

Fold systems of this kind were discovered initially by stereonet analyses of puzzling structural domains in the Pindos massifs. Figure 4a shows the orientation of original ridgecrest fabrics of cumulate layers that have been imprinted by a tectonic fabric in the near-moho rocks of the Drama-

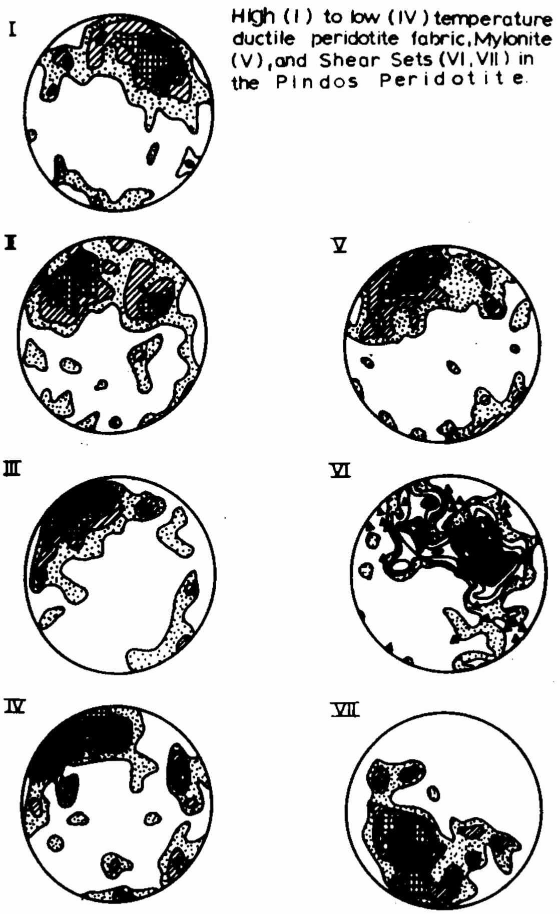

Fig.3: Stereonet representations of Pindos peridotite fabrics characteristic of decreasing thermal conditions (all nets display 1% countours, with maxima from 4 to 12%): I. High temperature orthopyroxene fabric (weak foliation of blocky pyroxene). n = 380. II. Strong foliation of blocky puroxene (initiation of shear strain fabrics). n = 452. III. Strong foliation of elongate orthopyroxene in neoblastic olivine matrix. n = 354. IV. Pervasive mylonitic fabric; pyroxene elongation in excess of 5:1, olivine and orthopyroxene neoblasts. n = 200. V. Mylonite zones. n = 200. VI. Triangles are poles to ductile/brittle shears. Old brittle shears are contoured, n = 109. VII. Brittle shear sets cross-cutting older shears. The younger are probably related to Eocene thrust of peridotite nappes over flysch. n = 82.

Σχ.3: Στερεογραφικές προβολές των πόλλων επίπεδων δομών απο το οφιολιθικό σύμπλεγμα της Πίνδου. I, II, III. Υψηλής θερμοκρασίας δομές, IV. Τυπική μυλονιτική φύλλωση: Η επιμήκυνση του ορθοπυρόξενου είναι μεγαλύτερη απο 5:1. V. Μυλονιτικές ζώνες. VI. Θραυσιγενείς ζώνες ολίσθησης. Τα τρίγωνα αντιπροσωπεύουν πόλους ζωνών ολίσθησης στο πεδίο όλκιμου/θραυσιγενούς. VII. Τεμνόμενα συστήματα θραυσιγενών ζωνών ολίσθησης. Τα νεότερα συνδένται πιθανά με την Ηωκαινική επώθηση των οφιολιθικών καλυμάτων πάνω στο φλύσχη.

la massif (Rassios, 1987). Figure 4b demonstrates essentially the same pattern among old and new fold axes in peridotites of the contiguous Salatoura massif. In each case, the geometry of the stereonets can be explained by a set of (older) northwest-southeast trending shallow fold axes imprinted by northeast-southwest axes including steeper plunge. Folds of this nature (figure 5) mimic tongue or imbricate shapes. Drag folds verging to the northeast show near horizontal northwest axes, and layers generally southwest dipping, but rotated and overturned in the fold nose area (figure 5a); Mylonitic transport bows the folds into ductile tear systems, generating axes which are near vertical (but which themselves may rotate into the verging direction, figure 5b).

If the ductile-brittle boundary is crossed, a series of imbricates is formed with high temperature and mylonitic fabric corresponding to the geometry of the brittle imbricate (Figure 5c). Terrane demonstrating folds of this kind in the Pindos occurs near the petrologic moho; single folds appear to be on the order of about 100 m wavelength. Terrane dominated by

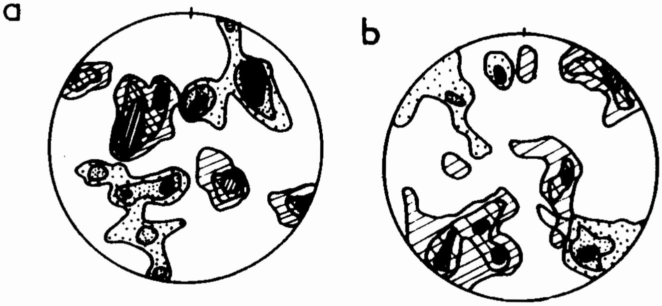

Fig.4: Stereonet of planar (4a) and linear (4b) structures representative of ductile imbricate sets. 4a shows contours of cumulate layers (stipled,n = 42) imprinted by a tectonic mineral foliation (hatched, n = 37).

Σχ.4: Διαγράμματα προβολών επίπεδων (4α) και γραμμικών (4β) δομών που αντιπροσωπεύουν συστήματα όλκιμων λεπιώσεων. Οι εστιγμένες περιοχές στο 4α αντιστοιχούν σε σωρειτική στρώση, ενώ οι γραμμοσκιασμένες σε ορυκτολογική τεκτονική φύλλωση.

ductile imbricate geometry has also been located in Othris in the west Smokovo and Mega Isoma areas (Rassios and Konstantopoulou, 1992), though relation to position of the petrologic moho is not known.

Individual ductile imbricates have been mapped on detailed structural maps (1: 1000 and 1:500 scale) of individual ore districts in Vourinos. Of the best, a ductile imbricate in the southwest of the Voidolakkos Ore District (figure 6) shows the characteristic rotation of high temperature fabric to an imbricate form; the fold is cross-cut by brittle, non-folded ramp shears which clearly show transport towards the northeast. Thus, the imbricate geometry precedes that of brittle ramping.

Structures with this tongue-shaped geometry must form very close to the ductile-brittle transition. They would be indicative of oceanic slabs which undergo continuous ductile deformation to the point of detachment.

III. Mylonite Zones of Vourinos

The significance of distinct mylonite zones has been best studied at Voidolakkos because of their economic importance (Grivas and others, 1993). Ross and others (1980) determine an oceanic lithospheric regime for formation of these zones; field studies published in Roberts and others (1988) noted the coincidence of ore bodies within continuations of the mylonite zones within dunite; Wright (1986) first pointed out the coincidence of mylonite geometry with brittle emplacement structures. As a result, a drilling programme for chrome ore was designed assuming that the geometry and displacement of the oceanic mylonite zones was analogous to later brittle emplacement tectonism. The programme (Grivas and others, 1993) was a success, with blind chrome ore bodies successfully targeted to depths of 180 m. The ore bodies (figure 7), previously sought in the subsurface as down-dip continuation of planar bodies with position resulting from ridge crest extensional tectonics, were investigated as linear features, elongate along the planar mylonite zones as features dragged parallel to emplacement motion during northeastern ductile verging; the mylonite zones are essentially ductile-phase emplacement ramps.

IV. The Coincidence of Aesthenospheric with brittle emplacement structures (Vourinos and Othris ophiolites)

The parallelism of ductile and brittle emplacement structures is best documented for Vourinos and the Mega Isoma massif in Othris (Rassios and Konstantopoulou, 1992). At Vourinos, the high temperature (1200 degrees

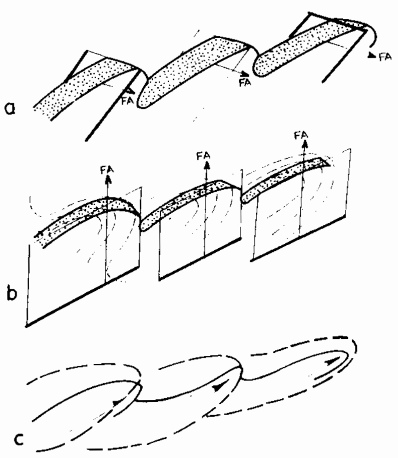

Fig.5: "Cartoon" representation of the geometry and evolution of ductile imbricates.5a shows development of drag folds delineated by high-temperature ridgecrest fabrics; these are rotated into and imprinted by lower temperature deformation fabrics (5b); detachment of the folds results in imbricates delineated by ductile fabrics (5c).

Σχ. 5: Σχηματική απεικόνιση της γεωμετρίας και εξέλιξης των όλκιμων λεπιώσεων. 5α. Συρρόμενες πτυχές που διαγράφονται από υψηλής θερμοκρασίας υφές που δημιουργήθηκαν κοντά στην ωκεάνεια ράχη: αυτές περιστράφησαν και επισκιάστηκαν από υφές χαμηλότερης θερμοκρασίας παραμόρφωσης (5β). Η αποκόλληση των πτυχών οδήγησε σε λεπίωση, που διαγράφεται από όλκιμες υφές (5γ)

C) fabrics of Ross and others (1980) parallel those of mylonitic and brittle fabrics for all detailed study districts (figure 5). A similar correspondence has been shown in form line maps of high-temperature, mylonitic, and brittle shear fabrics in the Mega Isoma massif of Othris (see Rassios and Konstantopoulou, 1992, figure 12). From this coincidence, we can deduce either that high temperature strucures were rotated into concurrence with brittle emplacement structures via some pre-brittle ductile phase of deformation, or that aesthenospheric and brittle strain were geometrically analogous.

OTHRIS-VOURINOS-PINDOS: A CONTIGUOUS OCEANIC SLAB AT THE TIME OF DETACHMENT

In the Pindos, Othris and Vourinos, high-temperature peridotite fabrics may have formed in deep spreading centre conditions, but their present orientation is that of obduction strain. We do not consider this coincidental; high temperature peridotite fabric has been rotated by ductile ramping or ductile differential motions that immediately precede brittle detachment, i.e., ductile shear strain is reconciled by structures similar in geometry to those of the brittle field. Orthopyroxene and spinel lineations (Roberts and others, 1988; Konstantopoulou, 1992, 1990, Konstantopoulou and Wright, 1990; Grivas and others, 1993; Frison, 1987; Rassios, 1987) show strong maxima plunging to the southwest: this lineation is a pervasive axial lineation in high temperature peridotites,and somewhat analogous to slickenslides in mylonitic peridotites. The geometry of strain at the ductile-brittle transition overlaps that of higher temperature structures and brittle field emplacement tectonism.

We cannot, then, reconstruct the original ridgecrest geometry of these ophiolites in the manner of Nicolas for Oman (1989). Our results would demand that the ridgecrest fabric parallells that of the emplacement front onto the continental margin, which in modern ocean systems is a rare configuration (e.g., consult Burke and Drake, 1974). We point out that any orientation of the ridgecrest (figure 9) deformed by northeast verging ductile deformation would result in essentially the same final geometry. The significance for our ophiolites is this: since the geometry of each at the ductile-brittle transition is the same, obviously they were emplaced

Fig.6: Individual tongue-shaped fold mapped at the Voidolakkos Ore District, Vourinos. Ore zones are black, dunite is stippled, harzburgite is white. High temperature form lines are solid; brittle shears dashed.

Σχ.6: Γλωσσοειδής πτυχή σε τμήμα της μεταλλοφόρας περιοχής του Βοϊδόλακκα,Βούρινου. Συμβολισμός: Μαύρο=μεταλλοφόρες ζώνες, εστιγμένη περιοχή=δουνίτης, λευκό=χαρτζβουργίτης, συνεχείς γραμμές=δομές υψηλής θερμοκρασίας, διακεκομένες=θραυσιγενείς ζώνες ολίσθησης.

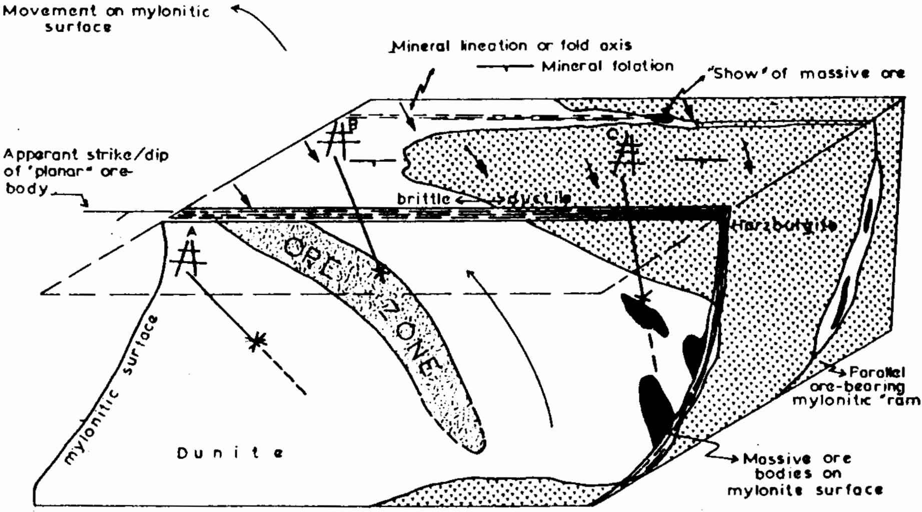

Fig.7: Schematic representation of the form of ore bodies on a mylonite zone, Voidolakkos, Greece. Three drill sites represent hypothetical targeting schemes: Drill "A" was sited to intercept the apparent strike/dip of a psudotabular exposed ore body; it was unsuccessful. Drill ÔBÕ was sited to intercept the mylonitic surface, regional lineation, and surficial spinel shows; it was successful. Drill "C" targeted a hypothetical massive orebody entrapped on the mylontic surface, down plunge of regional lineation at the intersection of a dunite-mylonite lense; it was successful.

Σχ.7: Σχηματική αναπαράσταση της μορφής των μεταλλοφόρων σωμάτων σε μια μυλονιτική ζώνη στο Βοϊδόλακκα Βούρινου. Τρεις γεωτρήσεις στοχεύουν υποθετικούς στόχους: Η γεώτρηση "Α" τοποθετήθηκε έτσι ώστε να τμήσει κατά διεύθυνση και κλίση ένα ψευδοπινακοειδές επιφανειακό σώμα (αποτυχημένη). Η γεώτρηση "Β" τοποθετήθηκε ώστε να τμήσει τη ζώνη μυλονιτίωσης σύμφωνα με την τοπική γράμμωση και τις επιφανειακές ενδείξεις χρωμίτη (επιτυχημένη). Η γεώτρηση "Γ" στόχευε ένα "τυφλό" συμπαγές χρωμιτικό σώμα παγιδευμένο μέσα στη μυλονιτική ζώνη, κατά τη βύθιση της τοπικής γράμμωσης στη διατομή της με ένα δουνιτικό μυλονιτικό φακό (επιτυχημένη).

as part of a larger, contiguous slab, most likely with the form first suggested by Rassios (1987).

While this conclusion reconciles structural similarity between Pindos, Vourinos, and Othris, it raises interest in the petrologic dissimilarities

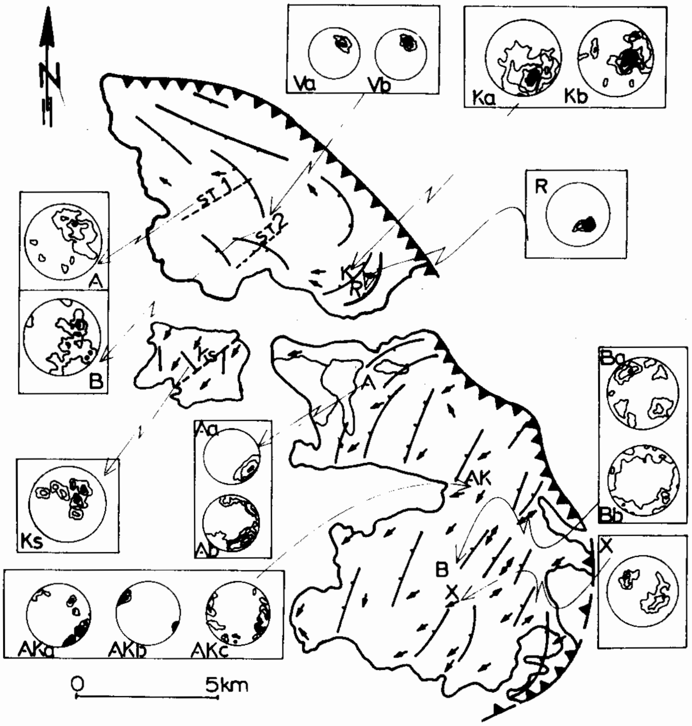

Fig.8: General pattern of high temperature plastic deformation structures in the Vourinos mantle sequence. Form lines include chrome ore layers, mantle layering, orthopyroxene and spinel foliation. Arrow represent spinel and/or orthopyroxene lineation. Pi diagrams (approximate 1% contours, maxima 4-10%) show range of measurements in well-studied ore districts. V = Voidolakkos: Va = orthopuroxene fos orthopyroxene foliation, n = 21; ST2 = Kerasitsa traverse orthopyroxene foliation, n = 50; ST1 = Grand Traverse orthopyroxene foliation, n = 102.

Σχ.8: Γενική μορφή των δομών υψηλής θερμοκρασίας παραμόρφωσης στη μανδυακή σειρά του Βούρινου. Οι σχηματικές γραμμές αντιπροσωπεύουν χρωμιτική στρώση, μανδυακή στρώση, φύλλωση σπινέλλιου και ορθοπυρόξενου. Τα βέλη αντιπροσωπεύουν γράμμωση του σπινέλλιου και/ή ορθοπυρόξενου.

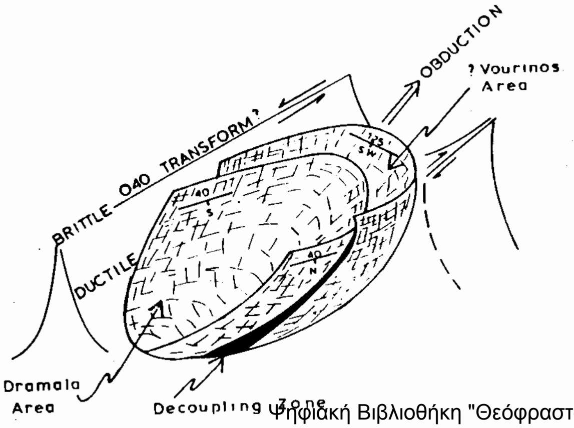

Fig.9: Cartoon reconstruction of the Pindos and Vourinos ophiolites in a single obducting slab, reconciling geometry and peridotite strain patterns (from Rassios, 1987).

Σχ.9: Σχηματική αναπαράσταση των οφιολίθων Πίνδου και Βούρινου σε μια ενιαία πλάκα με σύμφωνη γεωμετρία και τάση παραμόρφωσης (Rassios, 1987).

between these ophiolites; future models of the Greek Jurassic oceanic system must better reconcile the co-existence of MORB (Othris), fore arc (Vourinos) and complex ophiolite petrology (the Pindos) in a single oceanic basin rather than ascribing yet another Jurassic ocean basin for each petrologically distinct ophiolite.

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