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THE ANATOMY OF THE KRANIA BASIN, NORTH-WEST GREECE

J.WILSON

Abstract

The Krania Basin is Bartonian-Rupelian (Middle Eocene-Lower Oligocene) in age and occurs as a distinct embayment on the collapsing Pindos thrust-stack. The basin developed when the locus of thrusting lay relatively close to the to the west and was transported as a piggy-back basin, during the overthrusting of the Pindos Flysch by the Pindos thrust-stack in the Priabonian (Upper Eocene). Clastic sediments were deposited under marine conditions, possibly in an extension of the sea which covered the Pindos and Ionian Flysch basins, to the west.

Coarse breccias and olistoliths preserved at the base of the sequence (part of the Petra-Tripimeni Formation) are interpreted to have resulted from normal faulting. After a period of relative quiescence during the Priabonian (Upper Eocene), marked by the deposition of the Krania Marls, the Orliakis Limestone (Cretaceous cover to the Pindos Ophiolite) shed olistoliths southwards into the basin. This is interpreted as being due to deformation in the thrust-sheet during final overthrusting of the Pindos Flysch by the Pindos thrust-stack. It involved either strike-slip motion along the northern margin of the basin or block rotation along basement structures which tilted the northern part of the basin southwards. In the Lower Oligocene, the Krania Basin was folded, possibly in response to the overthrusting of the Apulian continental crust to the west and then unconformably overlain by sediments of the Meso-Hellenic Trough.

Field-relations suggest that the Krania Basin is an unusual type of piggy-back basin formed as a consequence of intermontane collapse on the active Pindos thrust-sheet.

Introduction

The aim of this paper is to summarise the development of a small precursor basin to the Meso-Hellenic Trough, previously referred to as the Gulf of Krania. It occurs as a distinct embayment within the Pindos Ophiolite and is separated from the Oligo-Miocene Meso-Hellenic Trough by a significant and laterally extensive unconformity.

During the formation of this small basin, the thrust-front was not far to the west and the Krania Basin formed and was transported piggy-back on the Pindos Ophiolite thrust-stack (Mercier, 1968; Jones and Robertson, 1991). The basin fill and its subsequent deformation prior to the Lower Oligocene unconformity, document a series of tectonic events linked both to basin formation and the deformation of the Pindos thrust-stack.

Department Of Geology and Geophysics, University of Edinburgh, West Mains Road, Edinburgh, EH9 3JW, U. K.

The Krania Basin

The "Gulf of Krania" was named and described by Brunn (1956), who was the first to recognise that the embayment contained Eocene sediments which were older than the Meso-Hellenic Trough. Subsequent studies by IGRS-IFP (1966) clarified aspects of the stratigraphy and correlated the Eocene of the Gulf of Krania with the Rizoma Marls in the southern Meso-Hellenic Trough, suggesting that they were deposited in a branch of the sea extending from the Pindos basin further west (Bizon, 1968). Most recently the stratigraphy and sedimentology have been mapped and described as part of a comparison of the molasse and flysch of Northern Greece (Desprairies,1977; Faugers,1975; Koumentakis,1980; Papanikolaou et al.,1988), leading to a better understanding of the relationship between tectonics and sedimentation in the area.

The name "Gulf of Krania" has been used simply to describe the geographical embayment in the Pindos Ophiolite, but in the context of this paper is no longer useful. The name "Krania Basin" is used here to refer specifically to those sediments deposited in the embayment beneath the Lower Oligocene unconformity, omitting the overlying Oligo-Miocene sediments of the true Meso-Hellenic Trough.

The Sedimentary Infill Of The Krania Basin

The sedimentary development of the Krania Basin can best be examined in the north of the area where there is better exposure, accessibility and a more clearly defined stratigraphic sequence. Semi-continuous sections occur along the main Krania-Kipourio road in the centre of the basin and the Microlivado-Monahiti-Trikomon track in the north. The type section for the oldest part of the sequence occurs along the Miliotikos-Microlivado river valley, about 1km south of Microlivado (Fig 1).

The sequence is here divided into four formations, as outlined below; a fifth formation of 15-30 meters has previously been described at the base of the sequence (Desprairies, 1977; Faugers, 1975), but has not been separated in this study as it is highly discontinuous and considered to be linked to the Petra-Tripimeni Formation in origin.

The Petra-Tripimeni Formation

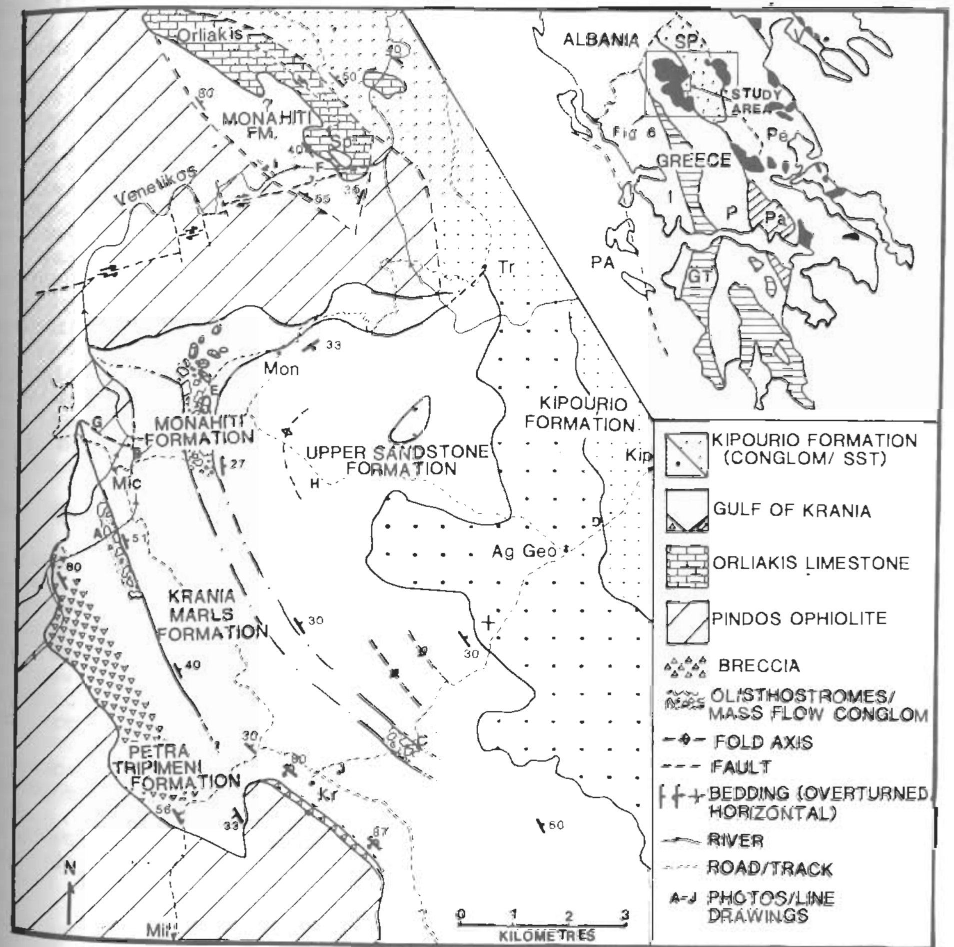
The basal sequence consists of extremely coarse breccias and olistolithic blocks. They have been folded to sub-vertical and consist almost entirely of ophiolitic debris, which demonstrates an inverse stratigraphy to that seen in the original ophiolite due to its progressive unroofing and erosion (Parrot, 1969). They are all highly angular, indicating a minimal amount of transport and the likely proximity of active syn-sedimentary fault scarps.

This sequence is followed by several hundred meters of thinly-bedded siltstones and fine sandstones, including nummulites of Bartonian age (Middle Eocene; Desprairies, 1977). Capping the formation are the conglomerates and olistoliths of the Microlivado member which form a slight topographic ridge just west of Microlivado village. It consists of a series of debris flows in which Cretaceous limestone clasts/olistoliths dominate and reach up to 15m in diameter.

The Krania Marls Formation

The Krania Marls consist of thin-bedded siltstones and sandstones which are most clearly exposed around Krania, where they directly onlap the ophiolite immediately west of the village. They can also be seen in a thicker more complete succession along the Milea-Krania road immediately to the west (Fig 1). Higher in the formation beds are

FIGURE 1. Simplified geological map of the northern Krania Basin and Orliakis Hills, modified after Faugers (1975). Additional key: Ag Geo/ Ageos Georgeos, Kip/ Kipourio, Kr/ Krania, Mic/ Microlivado, Mil/ Milea, Mon/ Monahiti, Sp/ Spileo, Tr/ Trikomon. Inset shows the study area and the main isopic zones of Greece. Key: PA/ Pre-Apulian zone, I/ Ionian zone, P/ Pindos zone, GT/ Gavrovo-Tripolitza zone, SP/ Sub-Pelagonian zone, Pe/ Pelagonian zone, V/ Vardar zone, Pa, Parnassos zone (after Aubouin, 1970)



often graded without any evidence of wave reworking, for example the Microlivado-Monahiti section which contains a matrix-supported mass flow deposit interbedded with graded siltstones and sandstones up to coarse sand grain-size.

The base of the Krania Marls is interpreted as a series of of fan-delta deposits and the overlying sequence coarsens to the north, interpreted as reflecting a proximal to distal facies change in relatively shallow-water turbidites, deposited not far beneath the storm wave-base.

The margins of the basin appear to have been tectonically quiescent at this time, although the thickness of the formation implies rapid subsidence. Foraminifera found in one fine-grained horizon date the Krania Marls as Priabonian (Upper Eocene; Desprairies, 1977), making them both contemporaneous and lithologically similar to the Rizoma Marls exposed at the south of the Meso-Hellenic Trough. (Bizon, 1968). It is therefore possible that the basin extended continuously between the two areas at this time.

The Monahiti Formation

The deposition of the Krania Marls was interrupted by the shedding of a series of coarse, matrix-supported conglomerates and olistostrome deposits into the basin (the Monahiti Formation). These deposits are dominated by limestone clasts/olistoliths, interbedded with sandstones and siltstones and thought to be the same age as the conglomerates and olistoliths which onlap the western margin of the Orliakis Limestone beneath Spileo.

Given the north-west to south-east palaeocurrent directions in the overlying turbidites and the proximal to distal relationship in the Krania Marls, the most likely source of the olistostromes is the Cretaceous Orliakis Limestone, which may have been uplifted at this time. This is supported by a distinct reduction in olistolith/clast size between exposures near Monahiti and Krania, also interpreted as a proximal to distal trend.

The Upper Sandstone Formation

The Upper Sandstones form a distinct topographic ridge west of Monahiti, where a sharp facies change is seen. Here the formation consists at its base of medium to coarse-grained, well sorted sands, whereas along the Krania-Kipourio road the change from the Monahiti Formation is more gradual. Abundant sole-marks at the base of the formation on the Krania-Kipourio road indicate both a north-west to south-east palaeocurrent direction and deeper-water conditions compared with those in which the coarser, more proximal sands were deposited, around Monahiti.

Nummulites indicate that this formation is Early Oligocene in age (I.G.R.S.-I.F.P. 1966), and therefore contemporaneous with the oldest sediments of the Ionian Flysch to the west (Alexander et al., 1990; Leigh, 1991). If the Pindos thrust-stack did not form too major a topographic feature at this time, it is possible that the two basins may have been connected.

The Kipourio Formation (Basal Meso-Hellenic Trough)

The basal conglomerates of the Kipourio Formation overlie the folded Upper Sandstone Formation on an irregular erosion surface, with an angular discordance of 10-20 degrees. The clasts consist mainly of ophiolite and Cretaceous limestone, with a noticeable lack of reworked material from beneath the unconformity, suggesting that the underlying beds were not extensively eroded.

The Kipourio Formation is Rupelian (Early Oligocene) in age, the equivalent of the conglomeratic Couches De Base and Eptahorion Formation which elsewhere onlap ophiolitic basement directly, along much of the western margin of the Meso-Hellenic Trough (Brunn, 1957). Given a Rupelian age for the underlying Upper Sandstone Formation, the unconformity represents a relatively short time period.

Deformation Of The Krania Basin

The Orliakis Hills And Northern Boundary Of The Krania Basin

The Orliakis Limestone forms a distinct north-west/south-east oriented ridge which is in fault contact with the Lower Oligocene deposits of the Meso-Hellenic Trough, dipping to the north-east. The fault here is clearly sub-vertical and is interpreted as a high-angle reverse fault, at least during its most recent phase of movement. This ties in with the folding of Oligocene beds along the east margin of the antiform that forms the Samarina Half-Window (Brunn, 1956), which is interpreted as being a Late Tertiary tip-line anticline to a blind, high-angle, north-east-verging reverse fault.

Uplift and erosion of the Orliakis Limestone during deposition in the Krania Basin is reflected in the series of limestone-dominated olistostromes and mass-flow deposits which both onlap the Orliakis ridge on its south-west flank and were shed southwards into the basin.

Exposure of the ophiolite/sediment contact along the northern basin margin is poor, but visibly faulted in places. Conglomerates are locally exposed along the contact and die out southwards, so may have been the result of syn-sedimentary fault activity during the Upper Eocene. Strike-slip movement along this margin (Papanikolaou, 1988), would account for the strong indentation of the basin into the Pindos Ophiolite, but a second possible interpretation is that the northern part of the basin lies on a fault-block which was tilted southwards during the Priabonian (Upper Eocene), uplifting the Orliakis area and causing increased subsidence further south.

The Western Margin

West of Krania village the outcrop pattern of the ophiolite forms a distinct kink in the basin margin and on the eastern edge of the structure both the ophiolite and overlying sediments are folded to vertical, or slightly overturned. The ophiolite immediately west of Krania is unconformably overlain by 20m of ophiolitic breccia and then directly by the Krania Marls, i.e. with a large part of the basal succession not deposited. This suggests that the area formed a palaeo-topographic high during deposition of the Petra-Tripimeni Formation The Krania structure is interpreted as a tip-line anticline to a blind east-verging reverse fault.

North-West of of Microlivado the margin is bounded by several faults which cut out the basal Petra-Tripimeni Formation, bringing the Krania Marls into fault contact with ophiolitic basement. A low-angle fault, probably a thrust, has resulted in ophiolite overlying the Krania Marls and is cut by north/south oriented steep normal faults This contrasts with the folded unconformable contacts exposed west of Krania and in the Miliotikos-Microlivado valley.

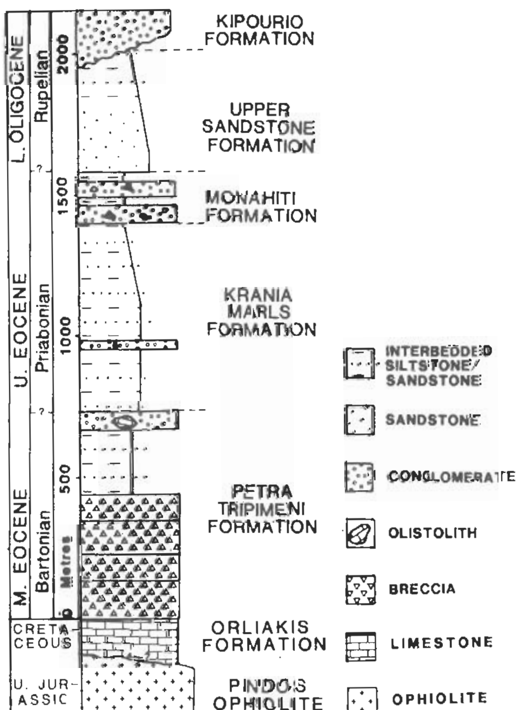
Intra-Basinal Deformation

The overall structure of the sediments within the northern part of the basin consists of an open fold in which beds dip away from both the western and northern margins of the basin. This involves a change in strike from north-west/south-east around the village of Krania, to north-east/south-west around the village of Monahiti in the north (Fig 1). Dips vary from 20-60 degrees over much of the area but become vertical or even overturned close to certain basin-bounding structures, such as west of Krania village.

Priabonian (Upper Eocene) assemblages recovered from limestone olistoliths within the Pindos Flysch (Brunn, 1957; Lorsang, 1977) indicate that the flysch was not overthrust by the Pindos thrust-stack until at least the Priabonian (Upper Eocene), proving that sedimentation within the Krania Basin had started before this final movement. The deformation affecting the basin may therefore be due to reactivation of basement structures during this final overthrusting of the Pindos Flysch by the Pindos thrust-stack, which was carrying the Krania Basin on its back.

The unconformably overlying sediments of the Meso-Hellenic Trough show no evidence of compressional deformation, which constrains the compressional deformation affecting the Krania Basin to being Lower Oligocene in age. This may also coincide with the end of movement along the basal thrust to the Pindos thrust-stack.

FIGURE 2. Semi-schematic composite log of the Krania basin.



Conclusions

1. The Krania Basin formed during the Middle Eocene in an embayment on the back of the Pindos thrust stack. The basin formed before the final overthrusting of the Pindos Flysch and as such may be classified as a "piggy-back" basin.

2. The Petra-Tripimeni Formation contains coarse breccias and olistoliths interpreted as reflecting the close proximity of extensional fault scarps along the western margin of the basin. Subsequently the Krania Formation was deposited in a deeper-water environment, when subsidence was continuing, but there is no evidence of fault activity along the basin margins at this time.

3. The Monahiti Formation contains limestone-dominated olistoliths shed from the Orliakis Limestone to the north. Deformation along this margin may be interpreted in one of two ways. Either as due to strike-slip faulting, or block rotation with movement on old lineaments at depth rotating the area southwards. This occurred during final overthrusting of the Pindos Flysch by the Pindos thrust-stack.

4. The sediments of the Upper Sandstone Formation were deposited prior to a final compressional episode which may be due to collision of thin-skinned thrust sheets with the continental crust of the Apulian microcontinental plate to the west.

5. The sediments of the Meso-Hellenic Trough which overlie the Krania basin contain only extensional faults, indicating a change in stress regime during the Lower Oligocene.

6. The Krania Basin is interpreted as an intermontane piggy-back basin.

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