A GEOPHYSICAL STUDY IN THE HELLENIC ARC BASED ON THE ANALYSIS OF SEISMIC REFLECTION DATA. IONIAN SEA, GREECE.

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A B S T R A C T

A geophysical study is carried out in the Ionian side of the Hellenic Arc, offshore western Peloponesse, Greece.

Seismic reflection data are used to study aspects of the tectonic deformation initiated by Miocene conversion of the previously passive margin to an active one.

As a result of the application of special processing techniques, features of compression caused by the westwards migration of Hellenide-driven thrusting as well as extensional characteristics related to active subduction in the Mediterranean Ridge, are delineated.

ΓΕΩΦΥΣΙΚΗ ΜΕΛΕΤΗ ΣΤΟ ΕΛΛΗΝΙΚΟ ΤΟΞΟ, ΒΑΣΙΣΜΕΝΗ ΣΤΗΝ ΕΙΔΙΚΗ ΕΠΕΞΕΡΓΑΣΙΑ ΣΕΙΣΜΙΚΩΝ ΔΕΔΟΜΕΝΩΝ ΑΝΑΚΛΑΣΗΣ

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Π Ε Ρ Ι Λ Η Ψ Η

Σεισμικά δεδομένα ανάκλασης χρησιμοποιούνται για την απεικόνιση της υποθαλάσσιας γεωλογίας στην περιοχή του Ελληνικού τόξου, δυτικά της Πελοποννήσου.

Η ειδική επεξεργασία αποκαλύπτει πτυχώσεις και ανάστροφα ρήγματα που σχετίζονται με την προς δυτικά επέκταση της συμπιεστικής τεκτονικής των Ελληνίδων κατά το Μειόκαινο. Τα χαρακτηριστικά εφελκυστικών τάσεων που αποκαλύπτονται στα ανατολικά με την δημιουργία ιζηματογενών λεκανών στην Δυτική Ελλάδα θεωρούνται αποτέλεσμα της καταβύθισης της Αφρικανικής πλάκας στην περιοχή της Μεσογειακής Ράχης.

INTRODUCTION

The area of study belongs to the Pre-Apulian zone and lies in the western end of the Hellenic Arc system, which is marked by the off-scraped sediments of the Mediterranean Ridge (Finetti, 1976). To the NE it is bounded by the Kephalonia fault, an important NE-SW striking lineament, which separates two major lithospheric domains.

Although the Pre-Apulian zone has been regarded as an undeformed western foreland to the Hellenic thrust belt, geological continuity on the mainland and the geometry and age

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relations of the arc strongly suggest that it must have originated by the conversion, probably in the Miocene, of the passive margin to an active one (Underhill, 1989). This late phase is also related to active subduction in the Mediterranean Ridge.

Two reflection seismic profiles with total length of 100 km, trending in a WSW - ENE direction, perpendicular to the Hellenide belts, are used in the present study (fig. 1).

This work provides seismic observations which underline the major geological features by imaging subsurface structures in an area of complex lateral variability. Special processing techniques are employed to enhance the quality of the data and remove undesirable multiples.

DATA DESCRIPTION

Acquisition of the reflection seismic data was carried out by Western Geophysical in 1980 on behalf of DEP (Public Petroleum Corporation, Greece). Data were recorded along a 2400 m long streamer on a group of 96 hydrophones at 25 m interval. The source used was a MAXIPULSE.

PROCESSING OF SEISMIC DATA

Processing was performed using a commercial (Western Geophysical) package.

The data (shot records) were initially deconvolved in the frequency domain in order to improve vertical resolution. This is because conventional predictive deconvolution failed to enhance deep reflections.

The output deconvolved data were "whitened" in a time variant mode over small frequency increments. Each trace was passed, in parallel, through 7 zero-phase filters spanning the range 5-60 Hz. Each filtered output was then time- variantly gained so that mean absolute amplitude becomes constant over the specified time gates. The sum of the gained traces for all the filters yields the output "whitened" trace.

The presence of multiple energy interfering with primary reflections is obvious in the original stacked sections (fig. 2). Velocity estimates also suffer from multiples (fig. 3). Velocity picks of water bottom multiples tend to concentrate in a low-velocity corridor (around the velocity of the water layer in figure 3a).

We have attacked water bottom multiples in the frequency-wavenumber domain: the data were NMO corrected by assigning a velocity function in the range between the primary and multiple velocities (dashed line in fig. 3a). The output gathers have all the primaries over-corrected whilst the multiples are undercorrected. Transformation into the F-K domain assign primaries into negative wavenumbers (the up- dip equivalent in t-x domain) and multiples into positive wavenumbers. Multiples were filtered out in the F-K domain. As a last step, the data were transformed to the t-x domain and inverse NMO was performed using the same intermediate function.

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Multiples have been attacked to a large extent by this approach. Resolution of the velocity spectra is improved (fig. 3b).

Multiple energy remains in the near offset traces (wavenumbers close to zero). Inside surgical mute was performed, in order to remove this effect from the gathers, at times corresponding to the two water-bottom multiples and that of an internal layer (attributed to the top of Mesozoic; Multiple of TM in fig. 2). Multiples appear clearly suppressed in the final section (fig. 4).

We have further processed the data (line Z209) by applying dip moveout correction (DMO) in the wavenumber domain after sorting into common offset. A zero-offset section is produced with dipping events moved to their true reflection points, and stacking velocities become independent of dip. The DMO effect is most significant for: large offsets; early times; steep dips; low velocities.

Better alignment is achieved for primary reflections of all dips (Deregowski, 1982; Hale, 1984).

As a result of this process high frequencies are enhanced in the upper part of the section and velocity estimates improved. This leads eventually to better migration results (fig. 4).

INTERPRETATION METHODS

Stacking velocities have been calculated at close CDP intervals using conventional velocity analysis techniques. Improved velocity spectra have been obtained after DMO corrections and the multiple elimination. Migration velocities used in figure 4 are also a final product of this process. These velocity estimates, especially interval velocities calculated via Dix formula, are of limited interpretation value.

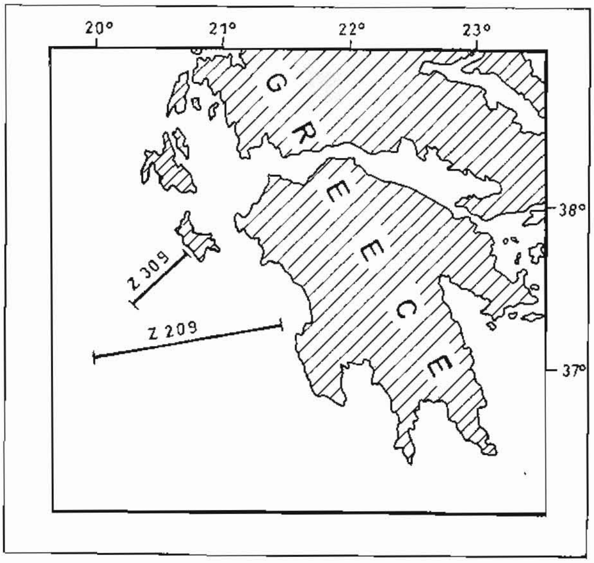

Fig.1. Location map.

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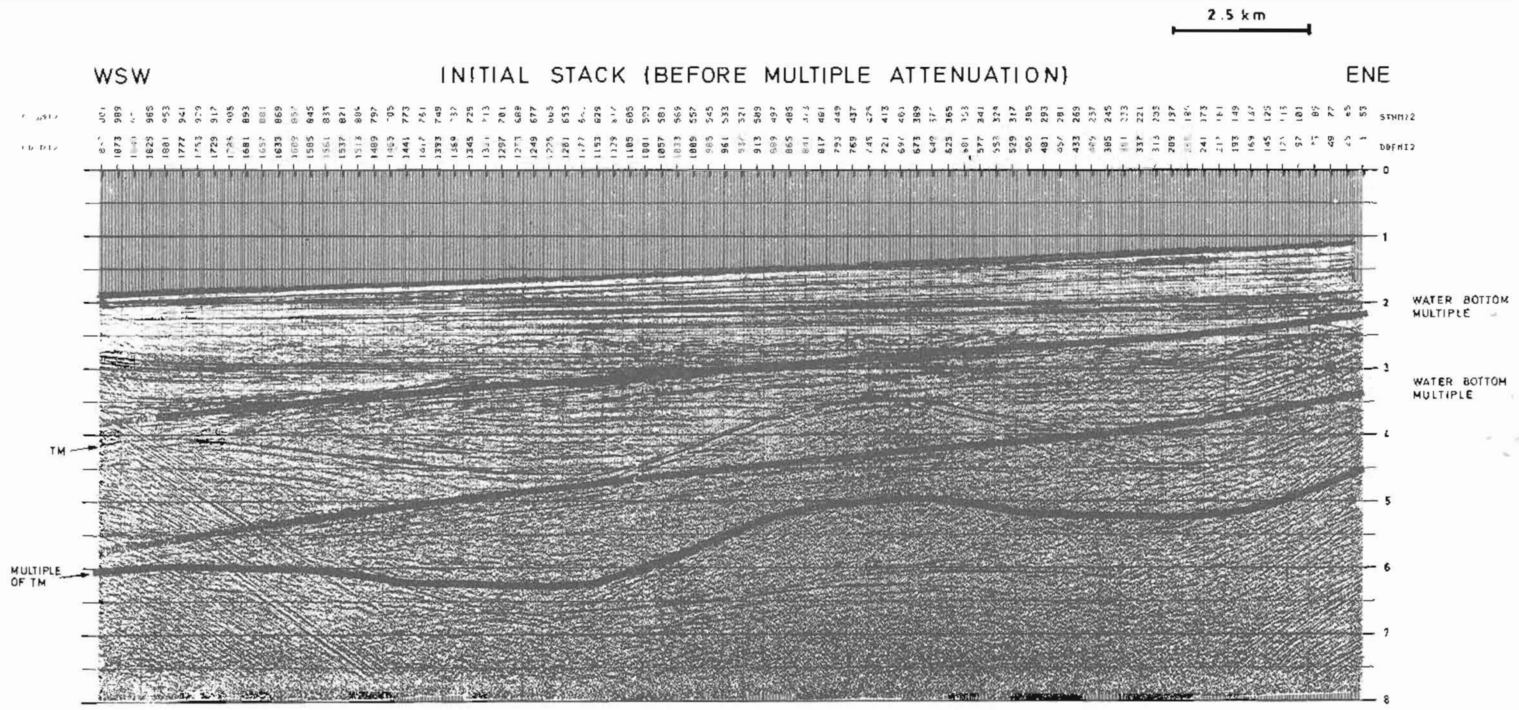

Fig.2. Line Z209 (eastern portion). Stack (before multiple attenuation).

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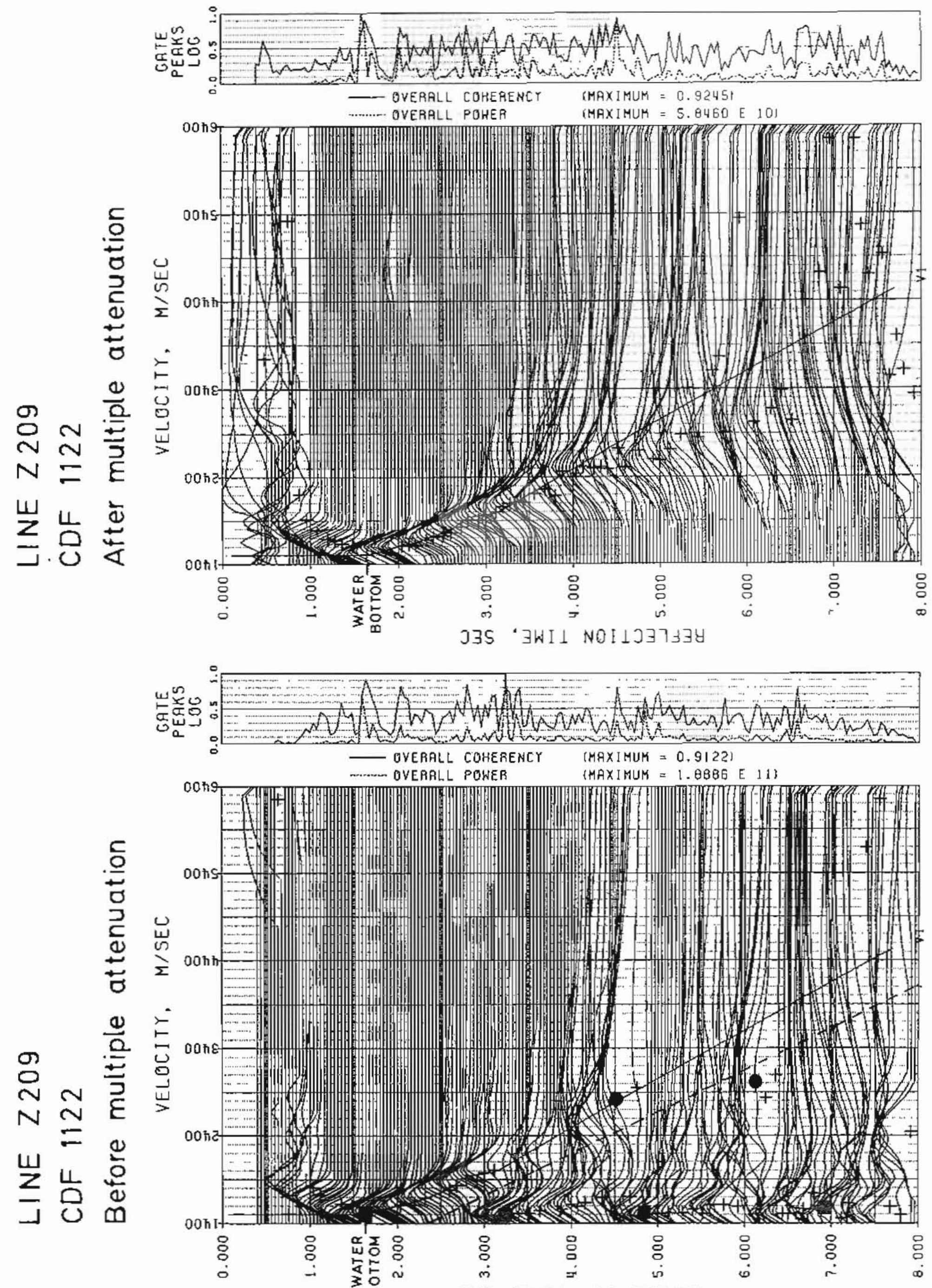

Fig.3. Velocity analysis on CDF 1122 (Fig.2). a.Before and b. After DMO and multiple attenuation.

Horizon velocity analysis was carried out along selected horizons (fig. 5). Velocity values were picked automatically at every second CDP, based on the maximum signal coherency. Final estimates were produced after several iterations. A vertical increase in velocity is related to increased compaction rates with age and depth. Lateral variability is observed between and below the two unconformities (Messinian evaporites and Top of Mesozoic in figure 4).

Attribute analysis

Viewing the seismic traces as analytic signals, they can be expressed in the form of a complex function (Taner, 1977), via the Hilbert transform.

Instantaneous attributes like envelope amplitude, phase, frequency and polarity can be estimated and interpreted in lithostratigraphic terms.

Envelope amplitude is phase independent and high values of it are often related to main lithological changes between adjacent formations, like unconformities or sharp discontinuities-differentiations in depositional environment (fig.8). Its stable character can also help in distinguishing events caused by a single reflector to that due to interference from a series of several reflections.

Instantaneous frequency is an important tool in defining the character of seismic events. Pinch-outs or limits between hydrocarbons and water tend to affect frequency response. Sometimes a "shadow" of low frequencies is observed below gas accummulations in sandstones or below oil traps.

A weighted average of this attribute, the "smoothed dominant frequency" is proved to be useful in enhancing reflection continuities (fig. 9).

DISCUSSION

Line Z309: Folding and east dipping thrusts which are evident in this section afford evidence of shortening (fig. 6). Thrusting is observed in Neogene and Quaternary sequences of the Ionian islands. By examining the nature of this deformation, Underhill (1989) has pointed out that the occurence of these structures could be accommodated into a model in which Hellenide-driven Mesozoic thrusting continued to migrate westwards during Cenozoic. They are also compatible with outer-arc compression, related to active subduction.

Line Z209: In the upper part of this section (fig. 4) a locally deformed, fault-bounded basin appears lying uncomformably above shortened sequences, probably of Mesozoic age. The younger sedimentary sequence (above 4.5 sec TWT) does not exhibit contractional structures and could be interpreted to form part of a E-W trending basin which belongs to the Aegean fore-arc domain, which is related to active subduction. This deformation style is more typical for basins in Western Mainland Greece (Mckenzie, 1978; Dewey and Sengor, 1979).

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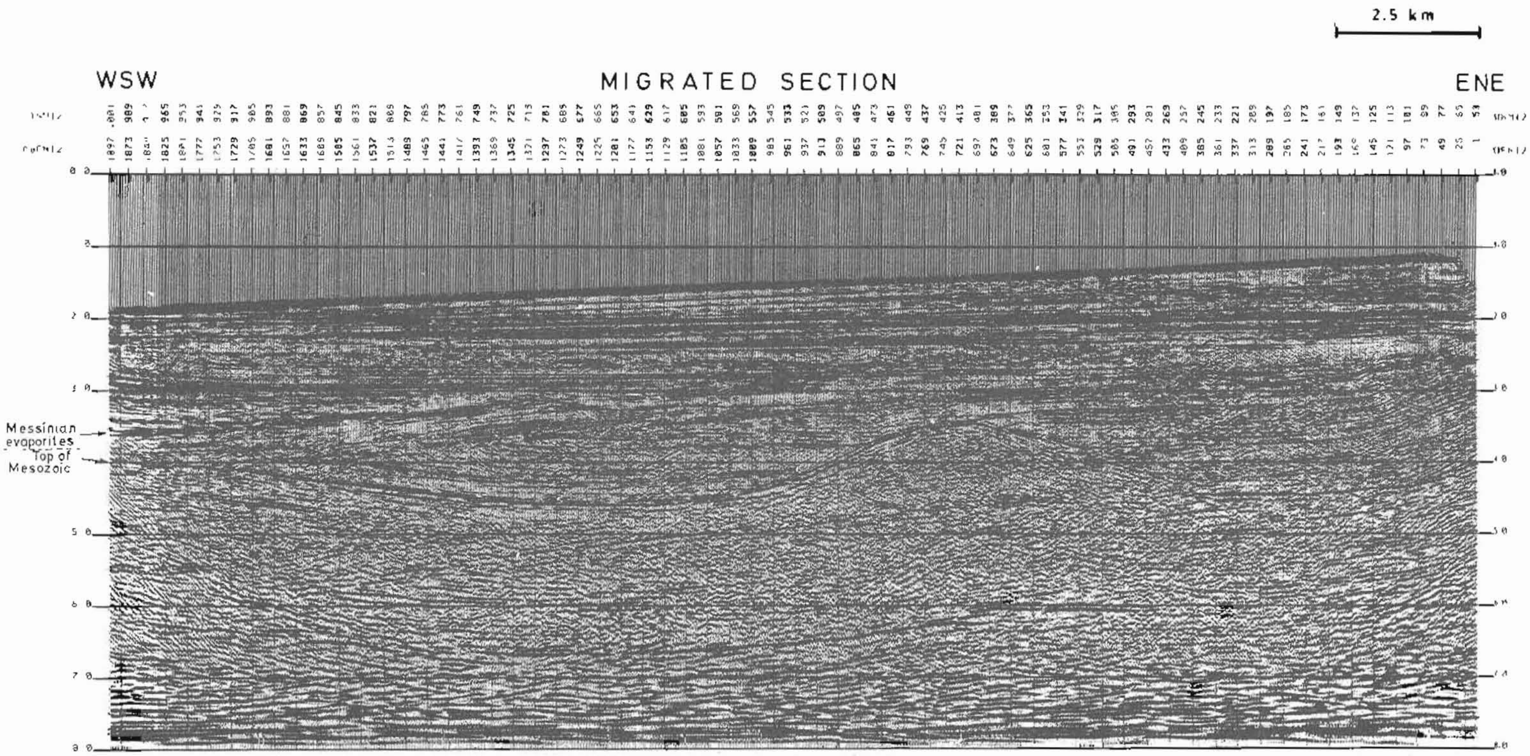

Fig.4. Line Z209 (eastern portion). Migrated section.

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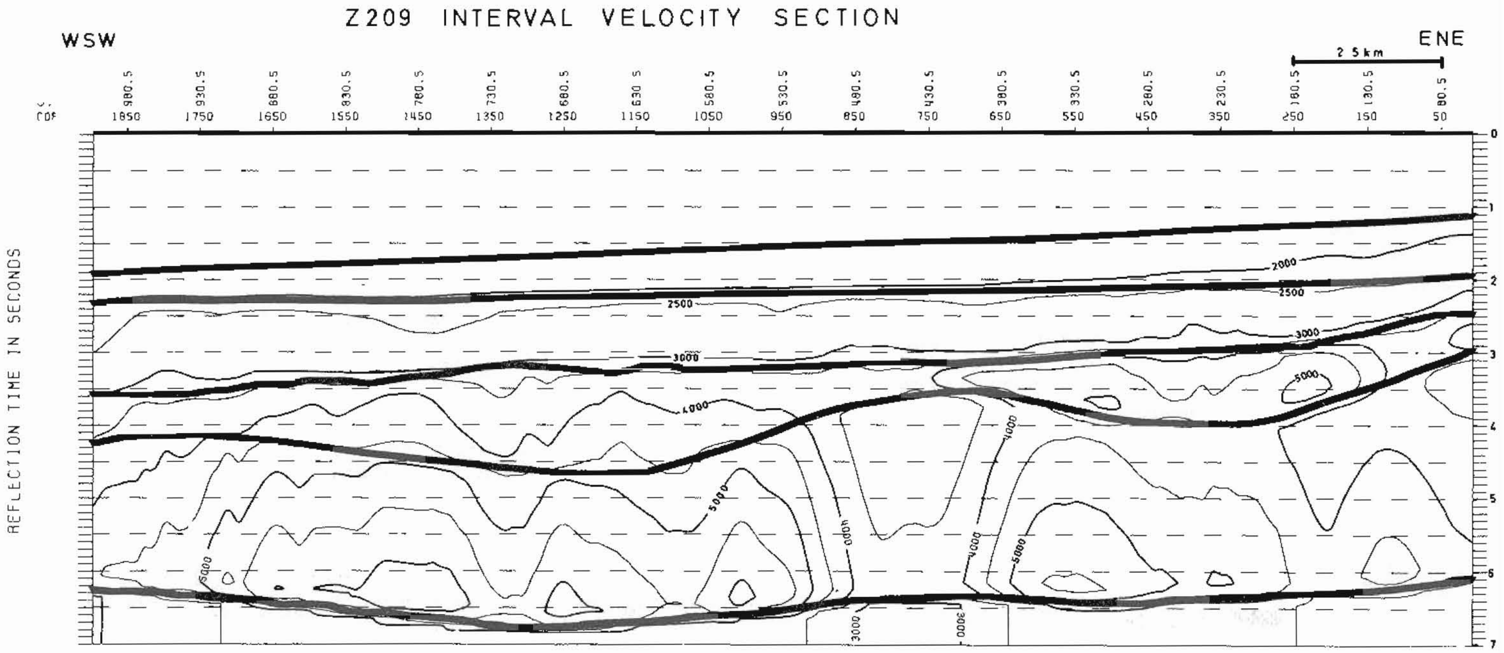

Fig.5. Z209: Interval velocity section.

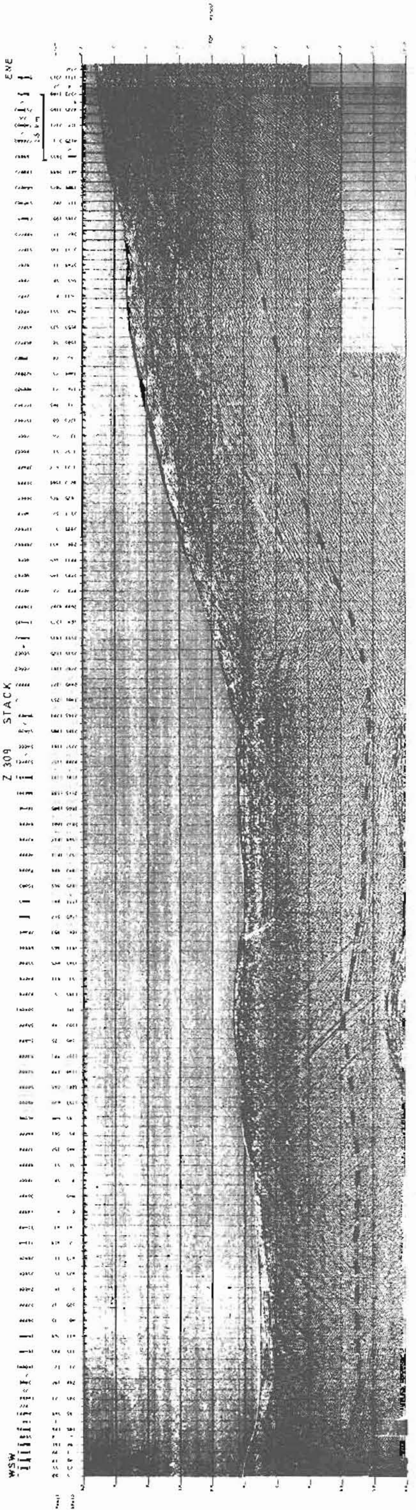

Fig.6. Line Z309 stack.

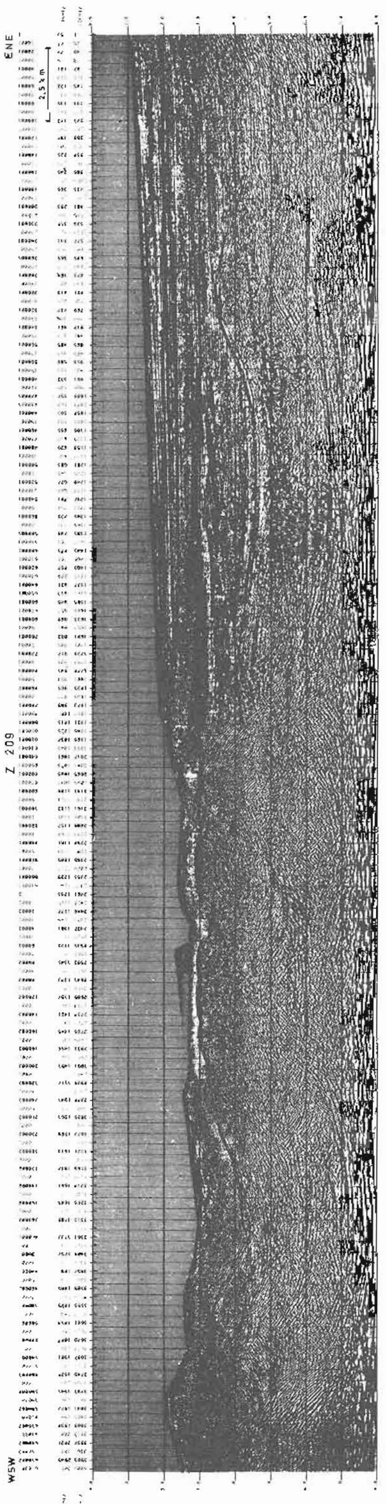

Fig.7. Line Z209: Migrated section.

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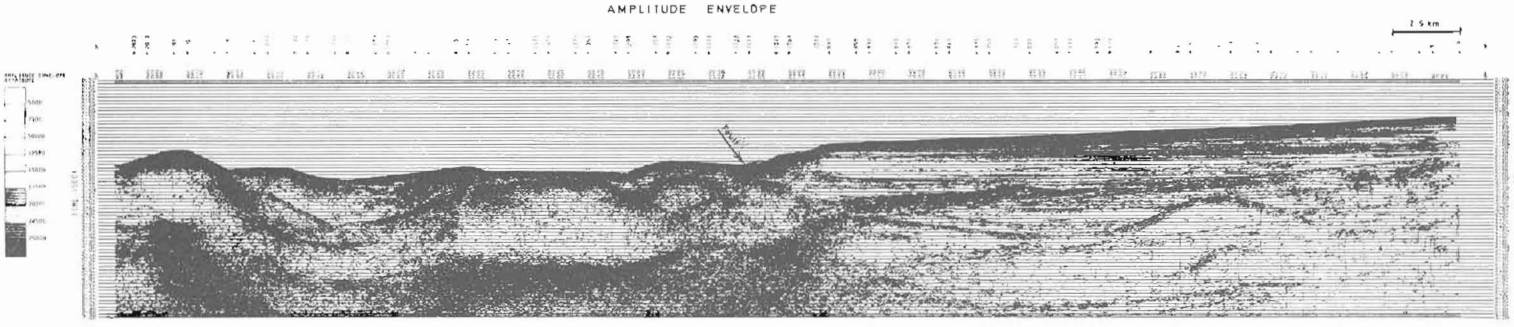

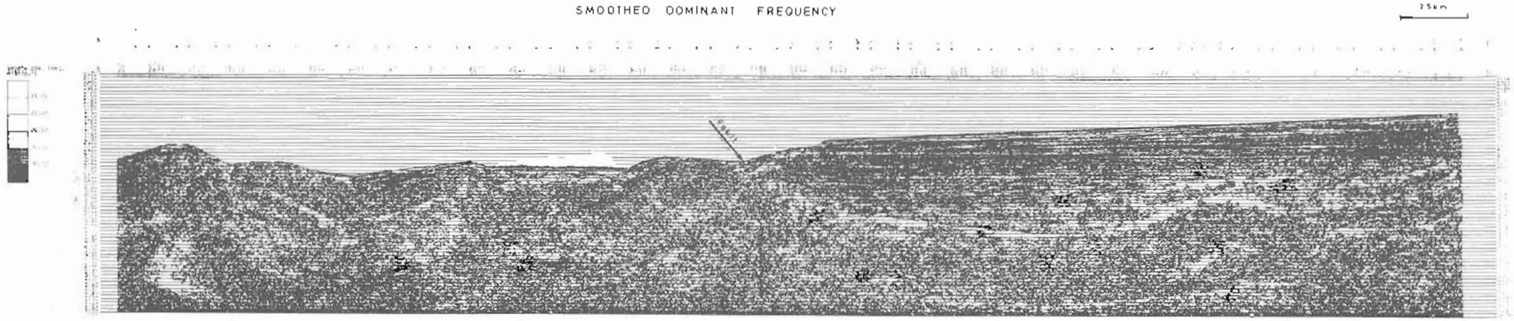

Fig.8. Z209 Amplitude envelope.   Fig.9. Z209 Smoothed dominant frequency.

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A number of unconformities appear in the post-Mesozoic sedimentary sequence, one of which (at about 3.2 sec TWT; fig. 4) may be related to the deposition of a thin sequence of Messinian evaporites. This is marked by high amplitude values in the attribute analysis (fig. 8). Drilling in the island of Zakynthos (Borehole Ampelokypi 1) revealed a sequence of thin layers of Messinian evaporites of total thickness 625 m, overlying an Upper Miocene sequence of clayeysands. Evaporites (mainly gypsum) were interpreted to have been deposited in a small marginal sea (Stylianou et. al., 1986).

To the west of the sedimentary sequence, line Z209 (extended section; CDPs 2000-4000 in figure 7) exhibits features with the chaotic characteristics of diapirs, which are attributed to Triassic evaporites intruding into the Pliocene. This is a frequent feature also on seismic lines lying to the north of Z209. Triassic evaporites outcrop in the island of Kephalonia and in Zakynthos beneath the uncomformable cover of Pliocene sediments. The western end of evaporite diapirism is considered to mark the limit of the Ionian zone based on field observations in the Ionian islands (Underhill, 1989). The continuation of this fault to the south of Zakynthos has not been defined. Our observations could be used to extrapolate or reassign this boundary offshore and perhaps redefine the boundary between the Ionian and Pre-Apulian zones in this area. This comes to strengthen our previous suggestion that Z209 exhibits similarities in deformation style with areas in the Ionian zone.

It should be noted that this extended to the west line is the result of standard processing. This cheaper approach was applied for a fast appraisal of some regional features. Amplitude envelope and smoothed dominant frequency was calculated (figs.8 and 9). The western flank of the E-W trending basin appeared marked by an east-dipping fault. It is clear that continuity of this feature was enhanced by the frequency approach.

A deep reflector is observed in the eastern part of Z209 and at about 6.5 sec (fig. 4). A good signal to noise ratio is maintained at this depth. The origin of this feature is not clear. Sediment underplating could be a possible explanation.

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