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ΠΡΟΓΝΩΣΗ ΓΙΑ ΤΗΝ ΠΙΘΑΝΗ ΠΑΡΟΥΣΙΑ ΜΕΤΑΛΛΟΦΟΡΩΝ ΥΔΡΟΘΕΡΜΙΚΩΝ ΔΙΑΛΥΜΑΤΩΝ ΚΑΙ / Η ΚΟΙΤΑΣΜΑΤΩΝ ΚΑΙ ΦΥΣΙΚΩΝ ΑΕΡΙΩΝ — ΥΔΡΟΓΟΝΑΘΡΑΚΩΝ ΣΤΗΝ ΤΑΦΡΟ ΤΟΥ ΒΟΡΕΙΟΥ ΑΙΓΑΙΟΥ, ΕΛΛΑΔΑ

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Abstract

The north-south tensional field combined with the concomitant presence of (i) relative crustal thinning, (ii) normal faulting, (iii) intrusives and/or volcanics, (iv) high heat flow, and (v) thick sedimentary pile along the Northern Aegean Trough characterize a rift valley. These characteristics suggest :

(1) The probable operation of hydrothermal circulation which results in the formation of metalliferous rocks and/or ore deposits at or near the sea-floor. The composition of the hydrothermal solutions is predicted to be Pb-Zn (Ag) - rich as it can be deduced from the nature of the rocks that fill-up the trough and the presence of the underlying continental crust.

(2) The potential formation of natural gas and hydrocarbon fields.

Περίληψη

Η Β-Ν τεκτονική εφελκυσμού σε συνδυασμό με την ταυτόχρονη παρουσία : (i) σχετικής λέπτυνσης του ηπειρωτικού φλοιού, (ii) κανονικής ρηγματογένεσης, (iii) διεισδύσεων και/η ηφαιστειακών, (iv)υψηλής γεωθερμικής βαθμίδας, και (v) ιζημάτων σημαντικού πάχους κατά μήκος της τάφρου του Βόρειου Αιγαίου χαρακτηριστικά υποδηλώνουν :

(1) Την πιθανή λειτουργία ανακυκλούμενου υδροθερμικού συστήματος που καταλήγει στην δημιουργία μεταλλοφόρων πετρωμάτων και/η κοιτασμάτων στο υποθαλάσσιο περιβάλλον. Η αναμενόμενη σύσταση των υδροθερμικών διαλυμάτων πρέπει να είναι εμπλουτισμένη σε Pb-Zn (Ag) όπως προκύπτει από τη φύση των πετρωμάτων που αποτελούν την πλήρωση της τάφρου και φυσικά την ανάπτυξη της πάνω σε ηπειρωτικό φλοιό.

(2) Την δυνατότητα δημιουργίας περιοχών πλούσιων σε φυσικά αέρια και υδρογονάνθρακες.

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Introduction

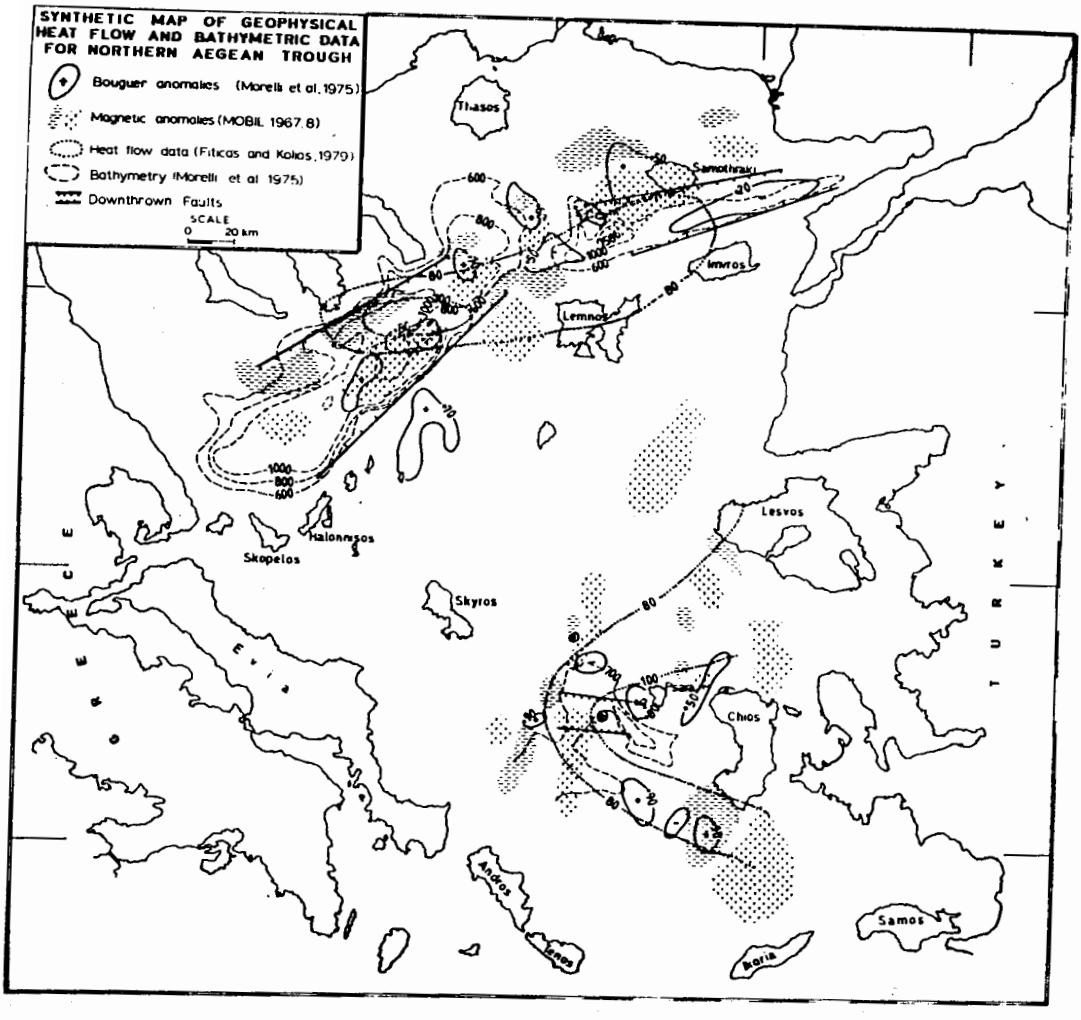
The Aegean sea in the Eastern Mediterranean is an epicontinental sea that occupies a subsided part of the Alpine chain (Stanley and Perissoratis, 1977). A steep-sided three hundred kilometers (300km) long through in the northern Aegean named the Northern Aegean Trough (NAT) is delineated by the six hundred meters (600m) isobath (fig.1). This trough is divided in two major basins by the Thasos-Limnos ridge. The western (or Sporades) basin which trends NE-SW has a maximum width of about fourty five kilometers(45km), and the eastern (or Saros) basin which trends ENE-WSW has a maximum width of about twenty three kilometers (23km). Both these basins narrow towards their NE ends. This study is a synthesis of all the available structural, geophysical and heat flow data towards a prognosis of the ore and hydrocarbon potentials of this universally rare geotectonic setting .

Structural and Bathymetric Data

The broad north Aegean area is presently dominated by an almost north-south tensional field and the accompanying normal faulting. This structural feature is in agreement with the observed relative crustal thinning along the NAT (Makris, 1977, Fig.2). It should be noted that the formation of the NAT is attributed by Allan and Morelli (1971) and Mckenzie (1972,1978) also to extensional tectonics. These data are in support of rifting; an event that was most likely initiated during Miocene as it is indicated by seismic and drill hole data (Lalechos and Savoyat, 1977). The Northern Aegean Trough area however seems to be structurally complicated as it is characterized by composite faulting (i.e. normal,thrust, strike-slip;Ritsema, 1974, Papazachos and Comninakis, 1976). These could be explained by the spatial variation through time of a local extensional field existing under the influence of an overall compressive regime. Such structurally complicated features characterize the pull-apart basins.

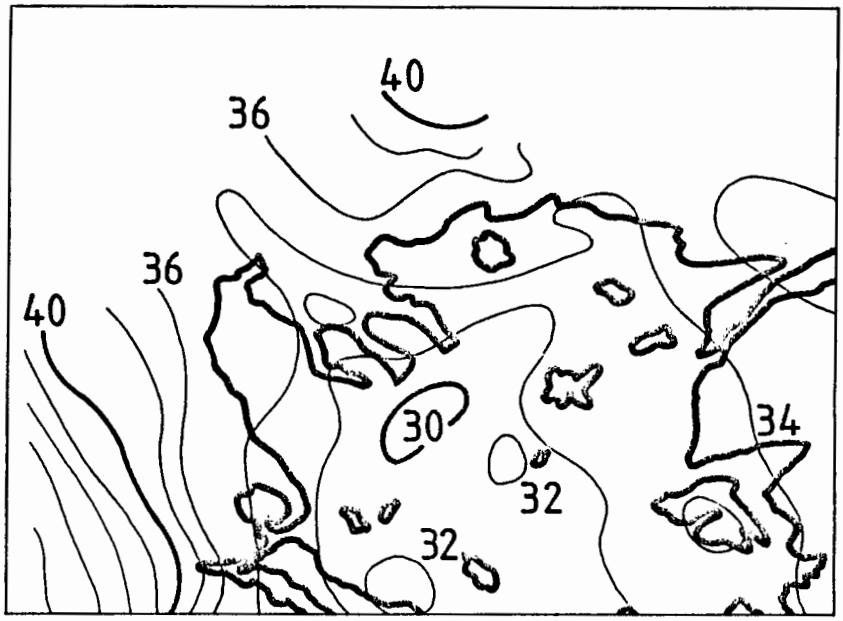
Magnetic Anomalies

The Northern Aegean Trough is characterized by strong magnetic anomalies



Εικ. 1. Συνθετικός χάρτης γεωφυσικών, θερμικής ροής και βαθυμετρικών στοιχείων γιά την τάφρο του Β.Αιγαίου και περιοχής δυτικά της Χίου.

Fig. 1. Synthetic map of geophysical, heat flow and bathmetric data for the Northern Aegean Trough and a region west of the Chios island.



Εικ. 2. Χάρτης της Moho στη τάφρο του Β.Αιγαίου όπως δίνεται από τον Makris (1977). Σημειώνεται η σχετική λέπτυνση του φλοιού στην τάφρο του Β.Αιγαίου.

Fig. 2. Moho-depth map in the Northern Aegean Region as given by Makris(1977). Note the relative crustal thinning in the NAT.

of several gammas which are distributed along its full length (Fig.1, Vogt and Higgs, 1963). These anomalies on the basis of their intensity and shape and the available seismic data (Lalechos and Sovoyat, 1977, fig.3) can be attributed to intrusives and/or volcanics. Similar features are also observed in the area west of the island of Chios (Fig. 1).

Gravity Anomalies

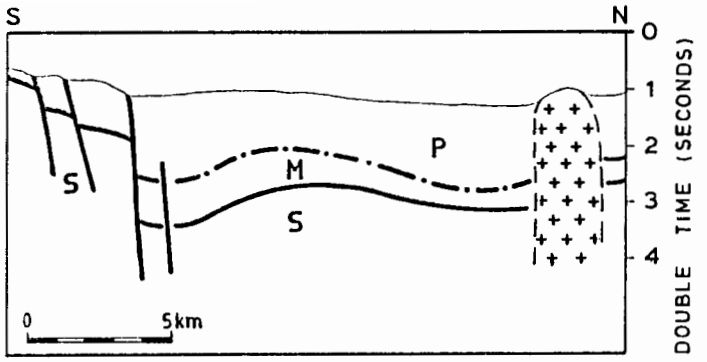
Along the NAT the presence of Bouguer gravity highs in the order of 80m gals is noted. These gravity highs coincide with magnetic anomalies (Fig.1) and can be assigned to intrusives and/or volcanics. The free air gravity anomalies that are observed in the same area indicate mass deficit which is attributed to a sedimentary cover (Morelli et al., 1975). This sedimentary cover has a thickness ranging from about 2 to 3.5 km and age wise extends from Miocene to recent (Lalechos and Savoyat, 1977, Fig.4). Part of this cover (100-1000m) consists of unconsolidated sediments (Needham et al., 1973, Stanley and Perissoratis, 1977).

Heat Flow Data

Heat flow (HF) measurements along the NAT are generally high ($>80 mW m^{-2}$, Jongsma, 1974, Fytikas and Kolios, 1974). The highest HF values ($>100 mW m^{-2}$ or $>$ 2.5 H.F.U.) are also associated with intense magnetic anomalies (60km west of Limnos, Fig.1). These data indicate the presence of a heat soure (e.g. magnatic stock) under the seafloor. In addition, hot springs with temperatures as high as 102°C are present in the islands of Lesvos, Limnos, Samothrace and Chios (Papadopoulos, 1982), suggesting the operation of geothermal systems on land which could well be extended as being operative on the seafloor at places where there is the concomitant presence of the data referred to above.

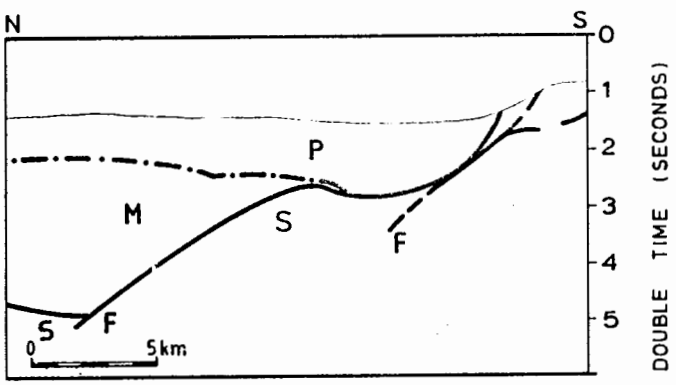
The Ore-Forming and Natural Gas Generation Processes.

There are five main requirements for formation and preservation of ore deposits on the seafloor (Fig.5). These are (Scott, 1985) :



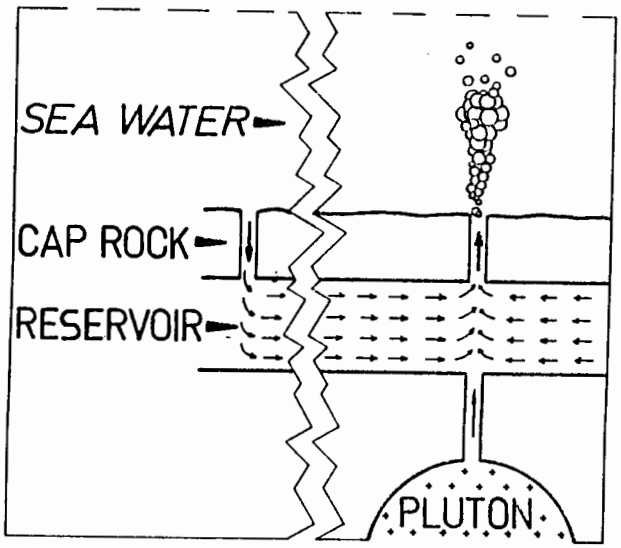
Εικ. 3. Β-Ν σεισμική τομή στην τάφρο του Β.Αιγαίου. Κανονικά Ρήγματα (F), Πλειοκαινικά (P) και Μειοκαινικά (M) στρώματα όπως και πιθανά εκρηξιγενή (T) και το υπόβαθρο (S) όπως δίνονται από τους Lalechos και Savoyat (1977).

Fig. 3. N-S seismic section in Northern Aegean Trough. Block faulting (F) Pliocene (P) and Miocene (M) sedimentary strata as well as possible intrusives (T) and the substratum (S) as given by Lalechos and Savoyat (1977) are shown.



Εικ. 4. Β-Ν σεισμική τομή βόρεια της λεκάνης των Σποράδων. Παχειά Πλειοκαινικά (P) και Μειοκαινικά (M) ιζήματα μαζί με το υπόβαθρο (S) και συνιζηματογενή ρήγματα (F) όπως δίνονται από τους Lalechos και Savoyat (1977).

Fig. 4. N-S Seismic section north of Sporades basin.A thick Pliocene (P) and Miocene (M) sedimentary pile together with the substratum (S) and concomitant faulting (F) as given by Lalechos and Savoyat (1977) are shown.



Εικ. 5. Γενικευμένο σύστημα υποθαλάσσιας υδροθερμικής ανακύκλωσης γιά τη γένεση κοιτασμάτων και μεταλλοφόρων πετρωμάτων (χωρίς κλίμακα, Scott, 1985).

Fig. 5. Generalized seafloor hydrothermal convection system for generation of ores or Metalliferous rocks (not drawn to scale, Scott, 1985).

1. A heat source of sufficient size to cause large-scale circulation of fluid through kilometers of seafloor rocks.

2. A fracture framework that permits fluid circulation through crust and focuses the discharge below and / or on the seafloor.

3. A hydrothermal fluid capable of carrying several parts per million metals and reduced sulphur in solution.

4. A mechanism for precipitating the ore minerals from the ascending fluid.

5. A flux of sedimentary and/or volcanic material immediately after deposition to burry the deposit (s).

The combination of intense fracturing and high heat flow-essential parameters for hydrothermal convection are met in rift systems (Cathles et al.1983). Such environment is that represented by the Northern Aegean Trough. The hydrothermal convection expected to occur in the study area can result in hot springs and metalliferous deposits near and/or on the seafloor. The predominant nature of the rock types that underly (e.g. continental crust) and fill (e.g.clastic sediments) the NAT suggest the composition of the ascending metalliferous brines would be Pb-Zn (Ag)-rich. The Red Sea and the Guayamas basin are the closest analogs to the hydrothermal system that is predicted to be in operation in the NAT. The only other example on a world wide scale that shares geological features similar to those described for the NAT and an operating hydrothermal system is yet to be found, is the Okinawa Trough west of Japan. Potentially existing hydrothermal systems in such geotectonically unique settings (i.e. seafloor developed on continental crust) have not been investigated yet both for their scientific worth and their resource potential.

The main parameters for natural gas-hydrocarbon generation are the following :

1. Thick pile of sedimets enriched in organic matter (e.g. marls, mudstones, sandstones).

2. Proper pressure and temperature conditions for oil maturation. These could be met in a thick sedimentary pile with or without the presence of concomitant heat source.

3. A proper tectonic system for the migration and concentration of hydrocarbons in existing traps.

The Northern Aegean Trough is an region that meets the requirements both for the operation of metalliferous hydrothermal systems and the formation and preservation of natural gas and hydrocarbons.

Concluding Remarks

Recent and presently active rift valleys provide the proper geotectonic setting for ore deposit and natural gas - hydrocarbon formation. The Northern Aegean Trough combines structural, gravity, magnetic, seismic and heat flow characteristics similar to rift valleys. Therefore, natural gas - hydrocarbons fields and mineral deposits of Pb-Zn (Ag) - rich composition could be presently forming or have been formed in the Northern Aegean Trough. The development of the NAT on continental crust makes it an invaluable case study both scientifically and for its resource potential.

References

Allan, T.D. and Morelli C. 1971, A. geophysical study of the Mediterranean Sea. Boll Geof. Teor. Appl. 13, 99- 142.

Cathles, L.M. Guber, A.T., Lenagh T.C., and Dudas, F.O., 1983. Kuroko-type massive sulphide deposits of Japan. Products of an aborted island-arc rift? Econ. Geol. Monogr. 5, 96-114.

Fytikas, M.and Kolios, N. 1979.Preliminary heat flow map of Greece. Terrestrial heat flow in Europe. Edit by V. Cermak and L. Rybach, 197-205

Jongsma, D. 1974. Heat flow in the Aegean Sea. Geoph. Jour R. Astr. Soc., 37 337- 346

Lalechos, N. and Savoyat, E., 1977. La sedimentation Neogene dans le fosse Nord Egeen , . VI Colloquium on the geology of the Aegean region. Proceedings V.II., 591- 603.

Makris, J., 1977. Seismic and gravity studies in Greece and geodynamic implication. VI Coll. Geol. Aegean Region; Proceedings 1, 61-85

Mc Kenzie, D. 1972. Active tectonics of the Mediterranean region . Geoph. J. Astr. Soc., 30, 109-185.

Mc Kenzie, D. 1978. Active tectonics of the Alpine-Himalayan belt. The Aegean sea and surrounding regions. Geoph. J.R. Astr. Soc., 55, 217-254

Morelli, C. Pisani, M. and Gantar , G. 1975. Geophysical studies in the Aegean sea and in the eastern Mediterranean. Boll Geof. Teor. Appl. 18, 127-167.

Needham, H.D. , Le Pichon, X. Melguen, M.Pautot, G.Renard, V. Avedik, F. and Carre, D. 1972. North Aegean Sea Trough. 1972.Jean Charcot cruise. Bull Geol. Soc.Greece, 10, 152-153

Papadopoulos, G.A, 1972. Contribution to the study of the active deep structure in the broad Aegean region.
Unpubl. Ph. Thesis. Univ. of Thessaloniki, 176 P.

Papazachos, B.C and Comninakis, P.E,1976. Modes of lithospheric interaction in the Aegean area. Inter. Symp. on the structural history of the Mediterranean basins. Split (Yugoslavia). Edit Techip, 319 - 331.

Ritsema, A.R.,1974. The earthquane mechanismus of the Balkan region.
Konink. Neder. Meteor Inst. de bilt, 36 P.

Scott, S.D.,1985. Seafloor polymetallic sulphide deposits.
Modern and Ancient. Marine Mining, 5, N2, 191- 212.

Stanley, D.J., and Perissoratis, C. 1977. Aegean sea ridge barrier and basin sedimentation patterns. Mar. Geol. 24, 97 - 107.

Vogt, P and Higgs, P. 1963. An aeromagnetic survey of the eastern Mediterranean sea and its interpretation E.P. S.L 5, 439- 448

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