TERRA RESEARCH

Optical parameters of maturity of organic matter dispersed in sediments: first results from the Central Apennines (Italy)

Sveva Corrado*

Dipartimento di Scienze Geologiche—Terza Università Statale, Via Ostiense, 169-00154 Roma, Italy

ABSTRACT

Levels of organic maturity of Mesozoic and Tertiary sequences outcropping in the Central Apennines have been established, using vitrinite reflectance techniques, the Thermal Alteration Index and fluorescence colours of organic matter dispersed in sediments. These results provide new constraints throughout the Meso-Cenozoic evolution of this crustal sector. In exploration geology, vitrinite reflectance provides data on hydrocarbon maturation by constraining organic matter maturity. In sedimentary basin modelling, it is adopted to define the palaeothermal regime. Vitrinite reflectance (R_o) also provides information on the burial history of sedimentary basins and may be employed to estimate tectonic uplift and erosion rates. Thermal Alteration Index (TAI) and fluorescence colour values can be correlated with R_o and may be used to estimate the degree of maturation when vitrinite is absent.

Samples derived from the Sabini and Tiburtini Mts, in slope facies between the Latium–Abruzzi carbonate Platform and the Umbria–Marche pelagic Basin; from the Simbruini and Ernici Mts, in carbonate Platform facies, and from upper Miocene turbiditic deposits outcropping between the Olevano–Antrodoco line, towards the West, and the Marsica slope facies, towards the East. Both the pre-terrigenous Meso-Cenozoic sequences show a low grade of organic maturity: the Sabini and Tiburtini Mts show R_o values that are less than 0.4%, and the Simbruini–Ernici Range show R_o values that range between 0.5% and 0.65%. Field analysis indicates that the cause of these low maturity levels is that thick sequences of turbidites were never deposited during the Neogene evolution of the Apennine thrust belt. Moreover, Upper Miocene turbiditic deposits also show low maturity levels, with R_o values that are less than 0.5%, indicating that these deposits were never overthrusted by huge volumes of rocks, during the chain building. The slight increase in the maturity level recorded in the Marsica area may be related to local heating along shear zones in areas of strike-slip tectonics.

Terra Nova, **7**, 2, 338–347, 1995.

INTRODUCTION

The Central Apennines fold & thrust belt developed in Neogene times according to a general piggy-back propagation of thrusting, accompanied by the development of progressively younger foredeep basins from the SW (Tyrrhenian margin) to the NE (Adriatic margin) and complicated by frequent out-of-sequence reactivations (Patacca *et al.*, 1990). Nevertheless, the detailed framework of the timing of thrusting and the mode of foreland basins formation in the western sector of the chain (Latium–Abruzzi Apennines) is neither understood completely nor interpreted univocally (Salvini and Tozzi, 1988; Cipollari and Cosentino, 1992; Patacca *et al.* 1992; Corrado and Montone, 1994). The main uncertainties refer to the space and time development of old foredeeps that nowadays are completely involved into the thrust belt.

The study of the maturity level of the organic matter dispersed in sediments through its optical parameters represents a powerful means of investigating the palaeogeothermic evolution of sedimentary basins both in undeformed and deformed conditions (Barker and Pawlewicz, 1986; Tissot *et al.*, 1987; Underwood *et al.* 1988) and may help constrain the geodynamic models of the Neogene evolution of this area.

In this paper, the first results of a study are presented related to the palaeogeothermal evolution of two sedimentary-structural domains developed in the western sector of the Central Apennines (Fig. 1): the first domain is represented by the Sabini and Tiburtini Mts Unit, in slope facies between the Latium–Abruzzi carbonate Platform and the Umbria–Marche pelagic Basin. The second domain is represented by the Simbruini–Ernici Mts Unit, belonging to the Latium–Abruzzi carbonate Platform. In addition, the turbiditic deposits outcropping between the Sabini and Tiburtini Mts Unit and the Marsica region have been analysed optically. These data are discussed and interpreted within the Meso-Cenozoic evolution of this sector of the Apennine chain.

The analytical techniques used are: composition analysis of organic matter;

---

*Correspondence: fax +39/6 57372827

Thermal Alteration Index (Staplin, 1969); vitrinite reflectance; and fluorescence colours. These optical methodologies have been in use for several years as a means of estimating organic matter composition, palaeotemperatures and geothermal gradients (Stach *et al.*, 1982; Tissot *et al.*, 1987) and are common in exploration geology.

GEOLOGICAL SETTING

The Central Apennines consists of different Meso-Cenozoic palaeogeographical domains that developed from Late Triassic times along the southern margin of the rifting Tethys (Parotto, 1980). This pattern is ruled by the development of the huge Latium–Abruzzi carbonate Platform that constitutes the nucleus of the belt and is surrounded by two main pelagic basins: the Umbria–Marche basin to the NW and the Molise basin to the SE with a wide belt of slope facies that connect them to the Platform (Fig. 1). These units differ in stratigraphy, structural style and main structural trends. Moreover, their original relationships are highly overprinted by the effects of the Neogene Apennine chain building.

This study focuses on different sectors of two of these palaeogeographical domains that are highly representative of the whole Apennine pattern, the Sabini and Tiburtini Mts (belonging to the western slope of the Latium–Abruzzi Platform area) and the Simbruini–Ernici Mts Range (belonging to the platform itself).

The Sabini and Tiburtini Mts Unit starts with a monotonous pack of dolostones and limestones in carbonate platform facies belonging to Upper Triassic *p.p.*–Lower Liassic. It evolves, from Middle Liassic to Lower Miocene, into a 3000 m-thick calcareous–marly–siliceous sequence, enriched by resedimented calcarenites deriving from the western margin of the Latium–Abruzzi carbonate Platform (Fig. 2A).

The structural pattern of the Sabini and Tiburtini Mts Unit is represented by an imbricate stack of at least four E-verging thrust sheets, that overthrusted as a whole on the Latium–Abruzzi carbonate Platform and its surrounding turbiditic units, along the Olevano–Antrodoco line (Cosentino and Parotto, 1992) (Fig. 1). Neogene mountain building began in Serravallian time and went on in a contractional regime with frequent reactivations until early Pliocene times (Parotto and Praturlon, 1975; Salvini and Tozzi, 1988).

The Simbruini–Ernici Mts Unit belongs to the Latium–Abruzzi Platform (Parotto and Praturlon, 1975) and is made up of a calcareous-dolomitic sequence, mainly in restricted-to-open carbonate platform facies, developed between Late Triassic and Late Cretaceous times. The 3500 m-thick Mesozoic sequence evolved, after the palaeogenic hiatus, into the Briozoans and Litotamnium Limestones (Lower–Middle Miocene) (Fig. 2B).

The structural style is ruled by the development of NE-verging thrust sheets overthrusted on Lower Messinian turbiditic deposits outcropping along the Roverto Valley. The Simbruini–Ernici Range is arranged into two topographical and structural sectors. The southwestern sector consists of thin thrust sheets involving only the upper portion of the Meso-Cenozoic stratigraphic sequence (Lower Cretaceous *p.p.*–Upper Tortonian) (Cavinato *et al.*, 1992). The northeastern sector is characterized by thicker thrust sheets involving the whole Meso-Cenozoic sequence (Devoto, 1967, 1970; Devoto and Parotto, 1967; Cavinato *et al.*, 1993) (Fig. 1).

During the Neogene chain building, the development of different foreland basins occurred along the front of the evolving thrust wedge. Their age is progressively younger from SW to NE, testifying to the general polarity of the Apennine system. As a result of this geodynamic process, the mainly carbonate sedimentation of the Meso-Cenozoic domains evolved into turbiditic deposits. The terrigenous sedimentation started with the Orbulina Marls, a few ten metres of hemipelagic marl rich in planktonic foraminifera, recording the flexure stage of basin development and continued with the deposition of a few thousand metres of turbiditic units.

METHODOLOGY

Composition of the organic matter dispersed in sediments

The composition classification of organic matter was performed through transmitted light analysis on palinologically prepared samples. The different macerals have been grouped into four categories whose frequency is expressed as percentages: (i) amorphous organic matter (AOM); (ii) phytoplankton of marine origin (MPH); (iii) herbaceous fragments of continental origin (CHF); (iv) wooden fragments of continental origin (CWF).

The investigation of monochromatic reflected light analysis allowed wooden fragments of continental origin to be further subdivided into vitrinite and inertinite groups (see Allen and Allen, 1990; Fig. 3).

Thermal Alteration Index (TAI)

The thermal evolution of the organic matter dispersed in sediments is recorded by colour changes in some of its macerals. This may be evaluated visually through transmitted light analysis and quantified through the chromatic scale codified by Staplin (1969) to define the TAI of Hydrocarbon-rich organic matter (e.g. spores and pollen). This parameter is less objective than vitrinite reflectance as it depends on the judgment of the observer, but it can often provide useful information when vitrinite is absent (Fig. 3).

Vitrinite reflectance

Vitrinite is derived from the thermal degradation of the wooden fragments of continental origin. Its reflectance depends on the thermal evolution of the sediments (see Stach *et al.*, 1982).

Random reflectance was measured under oil immersion with a Leitz Orthoplan MPV III microscope, in reflected monochromatic non-polarized light. On each sample about fifty measurements were performed on vitrinite fragments, never smaller than 5 nm and only slightly fractured and/or altered, and mean reflectance values (R_o) were calculated from the arithmetic mean of these measurements. On a few samples deriving from the Simbruini–Ernici Mts, reflectance measurements were performed on bitumen fragments and these values were converted in vitrinite equivalent reflectance data (R_{oeq}).

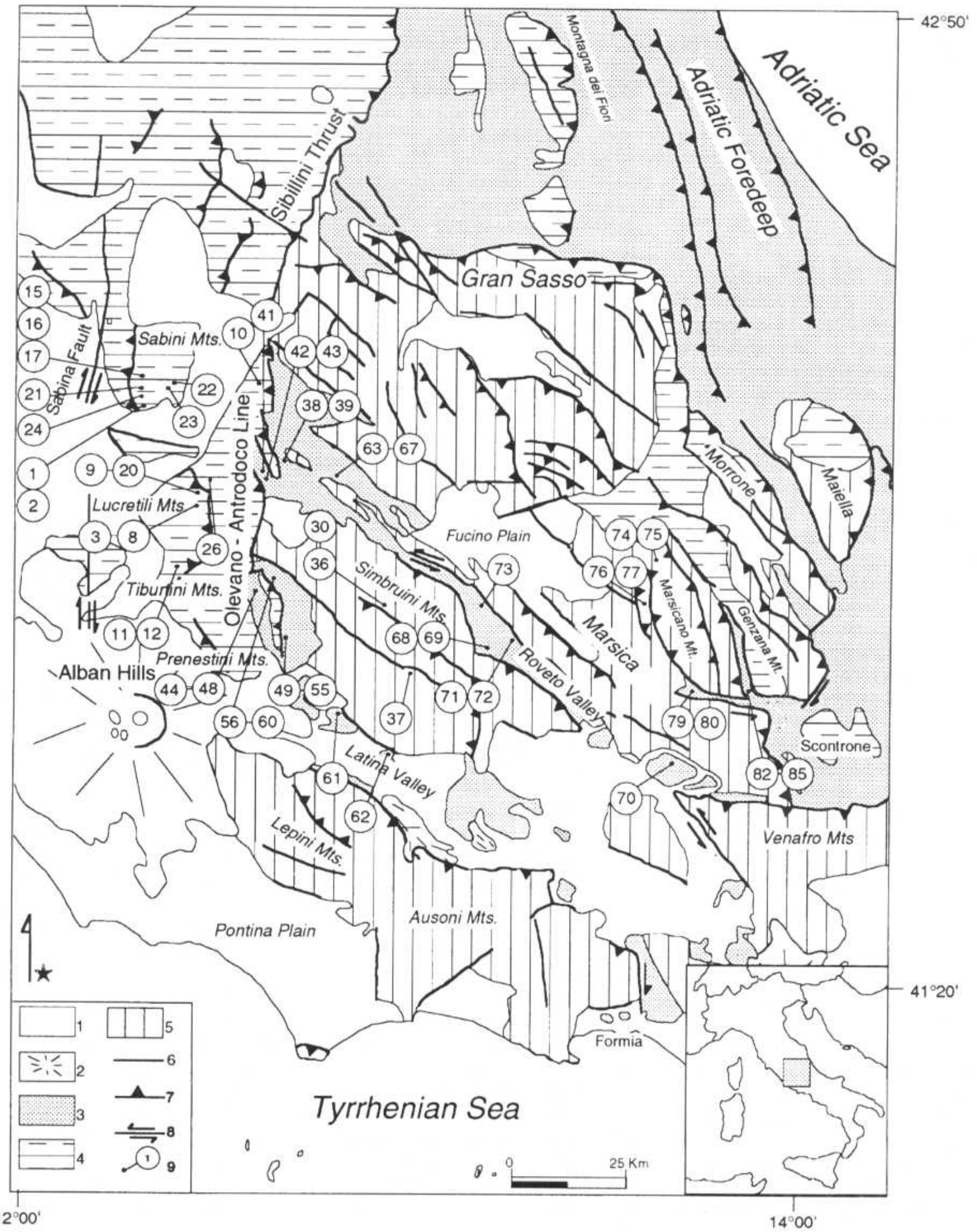

Fig. 1. *Samples location map (Structural scheme after Bigi et al., 1990, re-drawn and modified). Post-orogenic sedimentary sequences outcropping along the Tyrrhenian margin and within intramontane basins (Plio-Pleistocene); 2, volcanics (Pleistocene); 3, siliciclastic synorogenic deposits of the Latium–Abruzzi carbonate Platform (Tortonian–Messinian); Laga flysch (Messinian); Molise flysch; turbiditic foredeep deposits (Plio-Pleistocene); 4, pelagic basin and slope units of the Umbro-Sabine, Marsica and Gran Sasso areas (Upper Triassic–middle Miocene) 5, Latium-Abruzzi carbonate Platform units (Upper Triassic–Middle Miocene); 6, normal faults; 7, thrusts; 8, strike-slip faults; 9, sample location.*

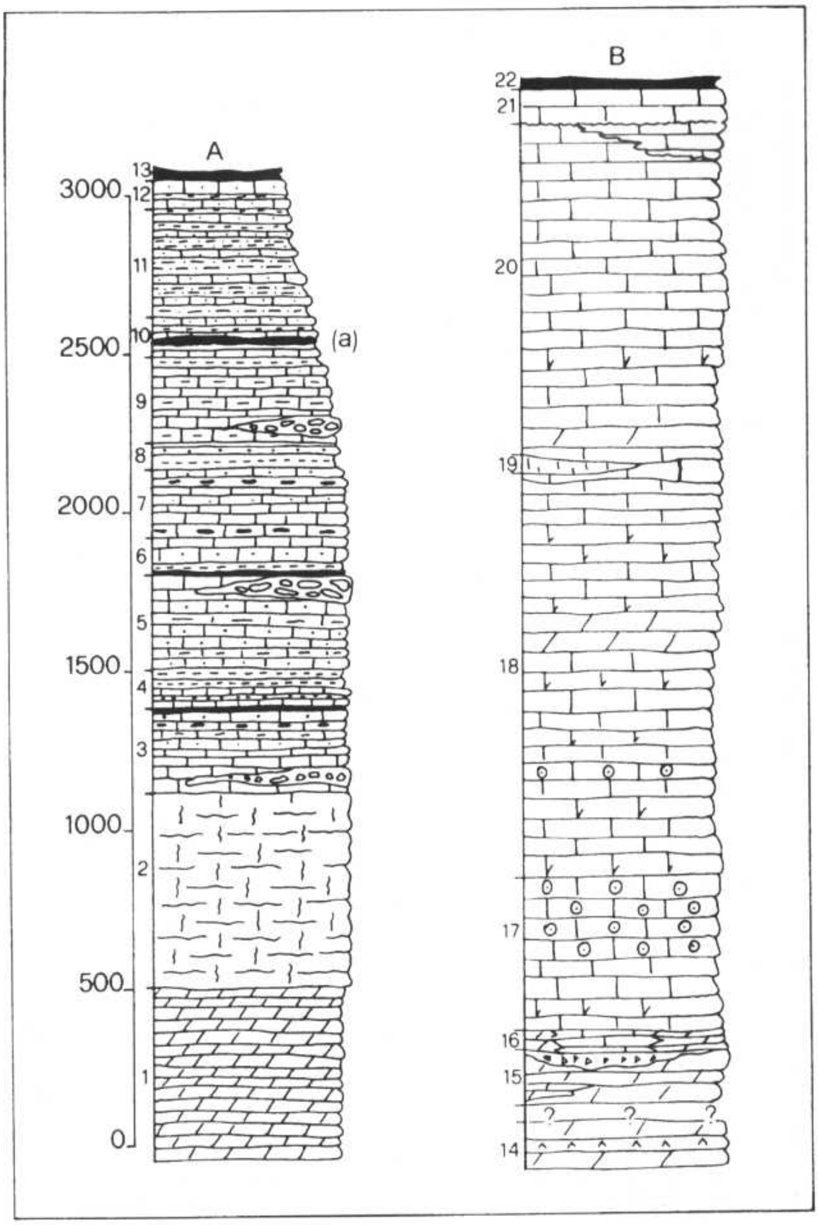

Fig. 2. *Stratigraphic setting of the Sabini and Tiburtini Mts (slope facies; A) and the Simbruini and Ernici Mts (carbonate platform facies; B). 1, Dolostones and dolomitic limestones (Upper Triassic* p.p.*); 2, Calcare massiccio (Hettangian–Sinemurian* p.p.*) 3, Corniola (Upper Sinemurian–Pliensbachian); 4, Rosso ammonitico (Aalenian–Toarcian); 5, Calcari granulari (Dogger–Malm* p.p.*); 6, Maiolica (Tithonian–Barremian); 7, Fucoidi Marls (Lower Aptian–Upper Albian); 8, Scaglia with Bonarelli level (a) (Cenomanian–Lower Eocene); 9, Macroforams marls and breccias or Scaglid cinerea (Middle Eocene–Oligocene); 10, Bisciaro Fm. (Aquitanian–Lower Langhian); 11, Guadagnolo Fm. (Langhian* p.p.*– Serravallian* p.p.*); 12, Briozoan and Litotamnium Limestones (Serravallian* p.p.*–Tortonian* p.p.*); 13, Orbulina Marls (Upper Tortonian); 14, Burano Anidrites (Triassic* p.p.*); 15, Dolostones and limestones with algae (Upper Triassic* p.p.*–Lias* p.p.*); 16, Ammonoid levels (Lias* p.p.*); 17, oolitic limestones (Dogger* p.p.*); 18, limestones with algae (Dogger* p.p.*– Lower Cretaceous* p.p.*); 19, Orbitolinae level (Aptian* p.p.*–Albian* p.p.*); 20, Rudist limestones (Upper Cretaceous* p.p.*); 21, Briozoans and Litotamnium limestones (Serravallian* p.p.*– Tortonian* p.p.*); 22, Orbulina Marls (Upper Tortonian–Lower Messinian).*

Fluorescence of organic matter

The study of colour and intensity of fluorescence recorded by liptinitic macerals is a powerful tool for evaluating the maturation rank of organic matter dispersed in sediments (Ottenjann *et al.*, 1975; Alpern, 1977) and can be compared with all the other optical parameters of organic maturity (Heroux *et al.*, 1979: Fig. 3). Samples prepared for vitrinite reflectance analysis were analysed in UV light too, to define a qualitative determination of fluorescence colours.

PRESENCE OF THE ORGANIC MATTER IN THE STUDY AREA

The organic matter used for optical maturity level determination comes entirely from Meso-Cenozoic lithostratigraphic units cropping out in the Central Apennines (Figs 1 and 2). They differ in age, sedimentary basin and geodynamic significance. Sample collected from the Sabini and Tiburtini sedimentary sequence come from the following lithostratigraphic units: Corniola (Pliensbachian–Upper Sinemurian); Fucoidi Marls (Lower Aptian–Upper Albian); Bonarelli horizon (Cenomanian–Turonian boundary); Macroforams marls and breccias or Scaglid cinerea (Middle Eocene–Oligocene); Bisciaro Fm. (Aquitanian–Lower Langhian); Guadagnolo Fm. (Langhian *p.p.*– Serravallian *p.p.*) (Parotto and Praturlon, 1975).

In the Simbruini–Ernici Range, in carbonate platform facies, sample collection concentrated on the Norian–Rethian stratigraphic unit of the sedimentary sequence, that contains an euxinic facies rich in organic matter (Fonte Santa Unit; see Damiani, 1975). In addition, cataclasites impregnated by bitumen and belonging to Lower Liassic Limestones were sampled in the Ernici Mts. In the other stratigraphic units in platform facies organic matter was almost absent. This might be expected because these carbonate rocks were deposited in an oxygen-rich environment where organic matter was oxidized easily.

The turbiditic deposits were sampled along the N–S to NW–SE oriented valleys where late Miocene flysch deposits crop out from the footwall of the Olevano–Antrodoco line to the Marsica area (Fig. 1). Vitrinite macerals derived