

The Oligocene volcano-sedimentary sequence of the Dipotama Basin, N. Greece: temporal relationships between Tertiary granites and volcanics, and implications for the regional tectonic evolution

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Abstract

The Oligocene volcano-sedimentary sequence of the Dipotama Basin, Rhodope zone, N. Greece is found unconformably overlying the Tertiary Skaloti granite along an erosional contact. The sequence comprises a thin basal conglomerate with granite and tuff pebbles in a calcitic matrix followed by lignite-bearing tuffs and distal airfall crystal and ash tuffs, with some physical reworking, overlain by an ignimbrite series. Diagenetic alteration in the volcano-sedimentary sequence is evident as calcification, while the lower part of the ignimbrite is clay-altered. The similar ages of the granite and overlying ignimbrite means that rapid uplift and erosion of about 6 km of crust occurred before subsidence allowed the development of a basin to contain the lignite-bearing sequence. The Dipotama Basin is one of a series of continental Tertiary basins covering a large part of the eastern Mediterranean, which became isolated during uplift, followed in Pliocene times by renewed inundation and a subsequent phase of uplift to produce the current mountain chain of N. Greece. Rapid uplift of thickened continental crust exhumed the Skaloti and other granites, while subsequent extensional collapse allowed the deposition of the Tertiary volcano-sedimentary sequences.

Introduction

Tertiary felsic to intermediate magmatic rocks are widely developed in the Rhodope zone of northern Greece where they cross cut and overlie a wide range of supracrustal rocks of the Rhodope crystalline basement. Age determinations show that the intrusive and extrusive rocks have overlapping ages (Eleftheriadis & Lippolt 1984, Innocenti et al. 1984). While the coeval nature of the plutonic and volcanic rocks has been recognised (e.g. Papadakis 1972, Del Moro et al. 1988), the temporal relationships between all the magmatic units have not yet

been established, though there is often a strong spatial link (e.g. Sideris 1975). The Tertiary Skaloti granite of the central Rhodope zone is overlain by a ca. 30 m thick, lignite bearing volcano-sedimentary sequence which in turn is overlain by a more than 500 m thick volcanic sequence, exposed in quarries to the NW of Dipotama, some 70 km east of Drama (Fig. 1). This paper describes the predominantly volcano-sedimentary succession of the Dipotama Basin, found in erosional contact with the granite, and the depositional environment and some implications on the uplift rate and tectonic evolution of the region are discussed.

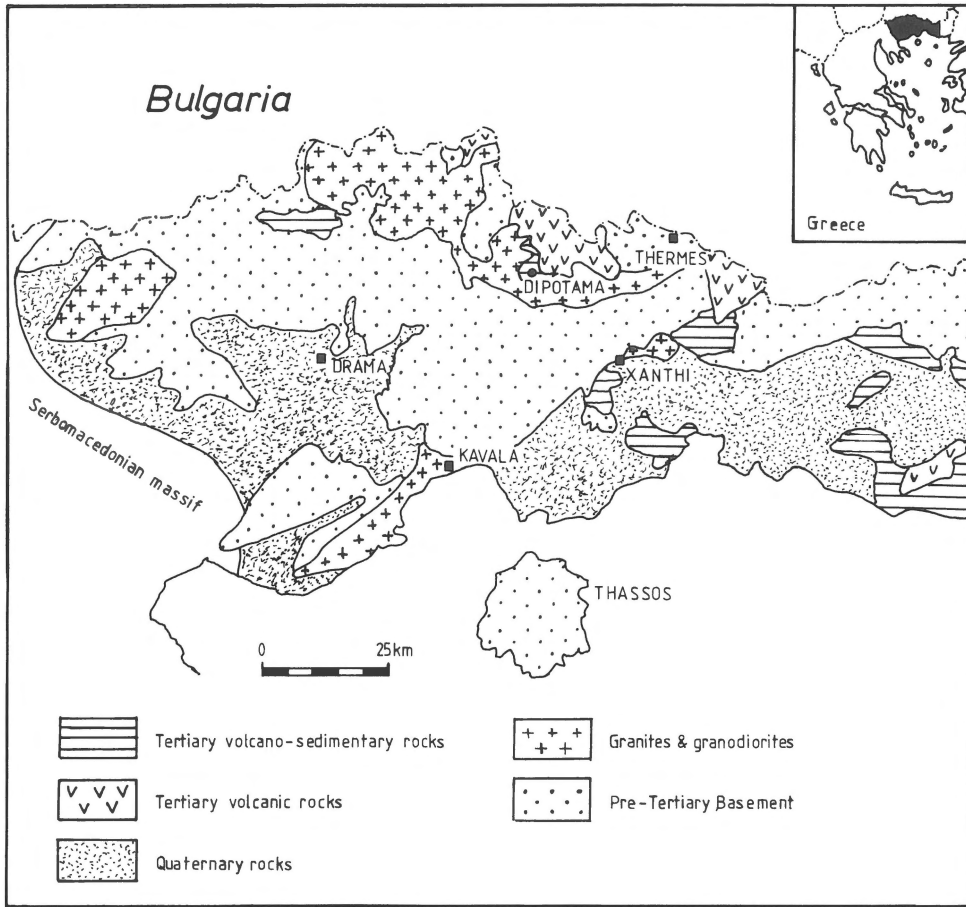


Fig. 1. Geological map of northern Greece, showing the location of the Dipotama quarries.

Geological synopsis

The tectonic evolution of N. Greece records a fragment of the collisional history of the African and European plates, and of the consumption of the intervening oceanic plate. The sequence of events in N. Greece can be divided into a pre-metamorphic, probably Mesozoic, stage of deposition of the units which later become the Rhodope crystalline basement. Crustal shortening and thickening followed, accompanied by prograde HP/LT metamorphism (e.g. Mposkos & Perdikatsis 1987, Mposkos 1989). The belt of Tertiary post-tectonic granites running across northern Greece was developed prior to a phase of rapid subsidence, and the development of shallow, predominantly non-marine sequences and thick ignimbrites, in rift-related basins (Innocenti et al. 1984).

The Rhodope Zone of northern Greece is a poly-metamorphic terrain bounded on the west by the Strimon thrust fault and continuing eastward into Turkey. Major thrust zones separate the region into distinct geological sub-provinces. Papanikolaou & Panagolopoulos (1981) divided western and central Rhodope into a lower and upper tectonic unit separated by an approximately SSE-NNW striking thrust plane. The upper tectonic unit comprise augen gneisses, migmatites, pelitic gneisses, amphibolites, calc-silicate rocks, ultramafic rocks and some marbles, and is thrust south over the lower tectonic unit comprising massive (Falakron) marble and banded marble, with some mica schist intercalations. Stratigraphically the Falakron marble belongs to the highest units (Zachos & Dimadis 1983). The Rhodope supracrustal sequence is con-

sidered to be the Mesozoic or older crystalline basement affected during different orogenic stages of the underthrusting of the African under the European plate (e.g. Del Moro et al. 1988).

High-P metamorphism is recorded in eclogitic amphibolites of central Rhodope (Liati 1986, 1988a), in eclogitic amphibolites of eastern Rhodope (Mposkos & Perdikatsis 1987, Liati & Mposkos 1989) and in chloritoid (-staurolite) schists of the eastern Rhodope (Mposkos 1988, 1989). This pre-Eocene event is followed by regional amphibolite facies metamorphism in early to mid-Eocene times (Liati 1986), overprinting the high-P facies. A retrograde greenschist facies metamorphism is commonly observed in amphibolites, metapelites and gneisses (Liati 1986, Mposkos & Perdikatsis 1987, Liati & Mposkos 1989). A lower and an upper tectonic unit have been recognised in eastern Rhodope by Mposkos et al. (1986, 1989), on the basis of differing metamorphic grade. The amphibolite facies metamorphic overprinting was accompanied by a high fluid volume, derived from dewatering of the metamorphic pile, as is evidenced by the CO₂-poor nature of the fluid phase (Liati 1988b) and the abundance of pegmatites.

Post-metamorphic magmatism produced the belt of Tertiary granites in N. Greece which extends from the Chalkidiki peninsula (De Wet et al. 1989) to eastern Thrace (Del Moro et al. 1988). Coeval with the granitoids are extensive felsic to intermediate volcanics that are structurally related to sedimentary basins which developed in and on the southern margin of the Rhodope crystalline basement (Innocenti et al. 1984). K/Ar mineral ages for plutonic rocks from the Greek part of the Rhodope Zone range from 26 to 38 Ma (Meyer 1968, Marakis 1969, Dürr et al. 1978, Sklavounos 1981). Radiometric data on the volcanic rocks reveal that the main volcanic activity occurred between Late Eocene to Oligocene and Miocene (Eleftheriadis & Lippolt 1984), with K/Ar and Rb/Sr whole rock ages of 30–33 Ma on volcanics to the east of Dipotama (Innocenti et al. 1984). The Skaloti granite (Fig. 1) is a large Tertiary intrusion extending into Bulgaria and interfingering in the east with Oligocene volcanics. Sklavounos & Kasoli-Fournaraki (1987) discussed the geochemistry

of the acid volcanoclastic occurrences in the broad area of Paranesti, characterizing them as high-K rhyolites. K/Ar mineral ages of around 38 Ma are given by Sklavounos (1981) for the Skaloti granite. Innocenti et al. (1984) mentioned the contact between the ignimbrites and underlying lignite-bearing sequence at Dipotama which they describe as comprising conglomerates and sandstones with marly intercalations, a sequence which in areas to the east attains a maximum thickness of 300 m. Tertiary basins are an important feature of the Aegean region; they are developed extensively on the Greek mainland as well as in southern Yugoslavia and western Anatolia, and are preserved on several Greek islands such as Samos (Stamatakis 1989), where the now submerged southern continental margin of the European plate protrudes above sea level. Foscolos et al. (1989) recorded some 60 lignite-bearing basins (including Samos) in Greece. Melidonis (1980) described uraniumiferous lignite beds in the predominantly sedimentary sequence of the Aemonion-Kotyli basin, 25 km east of the Dipotama basin, while uranium contents of up to 5000 ppm are reported in lignite from Dipotama, the U contained in autunite and metauranocircite (Foscolos et al. 1989). Lignites from N. Greece are enriched in As, Ba, Rb, Sr, Zr, Th, Y and REE as well as U relative to other Greek lignites (Foscolos et al. 1989), probably related to enhanced contents of these elements in underlying granitoids.

Field relationships of the Dipotama sequence

A ca. 30 m thick sequence of poorly lithified volcanic and sedimentary rocks containing two lignite horizons is exposed in quarries NW of the village of Dipotama. An erosional contact has been recognised between the volcano-sedimentary sequence and the underlying Skaloti granite, and the volcano-sedimentary sequence is disconformably overlain by a large ignimbrite unit. The units of the Dipotama sequence have been weakly folded by post-Oligocene rift movements, developing a synformal structure and a steepening of the erosional, unconformable contact with the granite. The quarries which originally worked lignite, are now aban-

doned. Spontaneous combustion in the southern end of one of the quarries has kept the lignite smouldering for several years.

The seven units of the Dipotama sequence are exposed in two adjacent quarries separated by a ridge of Skaloti granite (Fig. 2). The granite outcrops are rounded and friable, with a yellowish oxidized crust, and are overlain by a thin polymict conglomerate unit (1), about 1 m thick, with well rounded pebbles of tuff, 2–4 cm in diameter in a fine grained, sandy matrix. Some pebbles of Skaloti granite have been found in the conglomerate. Two lignite horizons (2a, c) separated by a well sorted, yellow, sandy unit (2b) overlie the conglomerate. Together the two lignite units attain a maximum thickness of some 2 m. The lignite units are in turn overlain by a 10 m thick sandy unit (3) with pebbles up to 4 cm in diameter. A unit of grey, finely banded ash tuffs (4) up to 2 m thick, is followed by a 10 m thick, structureless crystal tuff unit (5) with occasional xenoliths of more lithified volcanic material. An ignimbrite with fiamme up to 10 cm (unit 6) overlaps the sequence, and passes up into the massive rhyolitic series (unit 7) which marks the start of the Oligocene volcanics. The lower part of the ignimbrite contains clasts of lignite. While the upper part of the ignimbrite and rhyolite series consists of hard, flinty rocks, the lower part is soft and indurated, and the volcano-sedimentary sequence is poorly lithified. Pliocene boulder beds unconformably overlie the units of the Dipotama Basin, the unconformity steepened by late tectonic movements.

Petrography of the granite and volcano-sedimentary sequence

The Skaloti granite

This granite, exposed in the Dipotama quarries, is a weakly porphyritic, two feldspar, biotite leucogranite. Feldspar forms large anhedral to subhedral grains. Quartz forms large grains, which despite internal recrystallization and sutured boundaries still show occasional HT forms. The matrix is a fine grained, equigranular quartz-feldspar aggregate. The granite is undeformed, but shows in-

ipient recrystallization. The minor biotite is chloritized, and the cores of feldspar grains are altered. Detailed studies of the Skaloti granite are given by Sklavounos (1981), and Kotopouli (1981).

Unit 2b; unsorted crystal tuff

This unit is clearly volcanic, with angular, partly embayed HT quartz pseudomorphs and fragmented feldspar phenocrysts. Altered biotite grains are present in the matrix. Grains are angular to subangular, with angular splinters of crystal fragments present (Fig. 3a), which argues against any important tractive sediment transport. The matrix is a brownish glass with devitrification spherulites.

Unit 3; crystal rich tuff with rounded lithic fragments

The rock comprises subangular quartz and feldspar grains, with some minor biotite. The matrix is chiefly a brownish isotropic ash. Carbonate invades the matrix and replaces the feldspar on a grain by grain basis (Fig. 3b). Glass fragments, either isotropic or with devitrification spherulites are present. Accessory minerals include interstitial grey Mg chlorite, brownish clays, and spherulitic material. Pebbles found in this unit include alternating layers of crystal and ash tuff. The crystal tuff layers contain HT quartz pseudomorphs that are present as angular fragments, sometimes embayed or with magmatic crystal faces, as well as feldspar fragments, forming well defined but discontinuous layers separated by finer grained, presumably ash layers. There is a large range in grain sizes. Accessory minerals include greenish biotite. The matrix is a brownish volcanic ash undergoing incipient sericitization and/or clay formation. Other pebbles include intensively deformed, medium-grained Skaloti granite, with cracked and rotated feldspars, ribbon quartz, and very minor chloritized biotite. Some pebbles of welded crystal-rich ash flow were found, comprising fragments of rhyolite, HT quartz phenocrysts, feldspar and some biotite in a matrix of brownish glass. Shards are abundant, but without much welding since they occur in protected inter-fragmental positions. Pebbles of marble with an equigranular recrystallized texture, cut by zones of finer grained carbonate and quartz are also present in this unit.

Unit 4; banded fine grained ash tuff

The rock shows a few larger quartz and feldspar phenocrysts embedded in the finer grained layers comprising fragments of quartz and feldspar (Fig. 3c). There is a limited range in grain size, perhaps resulting from mechanical sorting during wind transport. Kinked, magmatic, oxidized biotites are present along with some brownish glassy fragments, which are still isotropic. The matrix consists of very fine grained sericite, possibly originating from the sericitization of small plagioclase prisms, and of glass. In addition, there is some carbonate alteration.

Unit 5; crystal rich tuff

This massive unit comprises grains of quartz, feldspar and secondary carbonate with a small percentage of matrix material (Fig. 3d). Quartz and feldspar are of magmatic origin, often still angular with magmatic forms, but some grain rounding is evident. There is a large range in grain size, and the rock is massive and unsorted. The carbonate grains argue against a purely volcanic origin. Carbonate is present in the matrix, as are small, diagenetic chlorite grains. Xenoliths in this unit include carbonate-cemented crystal lithic tuffite (Fig. 3e). Smaller grains of granitic derivation with quartz, feldspar and myrmekite are also present, along with larger fragments of devitrified rhyolitic glass.

Unit 6; lower part of ignimbrite

This unit contains large angular to subangular embayed phenocrysts of HT quartz pseudomorphs, and angular, subhedral or fragmented plagioclase phenocrysts showing magmatic oscillatory zoning. The matrix comprises a debris of smaller quartz and feldspar phenocryst fragments. Relict glassy fragments, now devitrified, are also present, containing few and always small phenocrysts. Some pumice fragments show flattened vesicles.

Unit 7; ignimbrite

This unit contains large embayed subhedral HT quartz, as well as smaller fragments, and subhedral and cracked feldspar showing oscillatory zoning. The numerous glass inclusions in feldspar, often developing an almost poikilitic texture is evidence

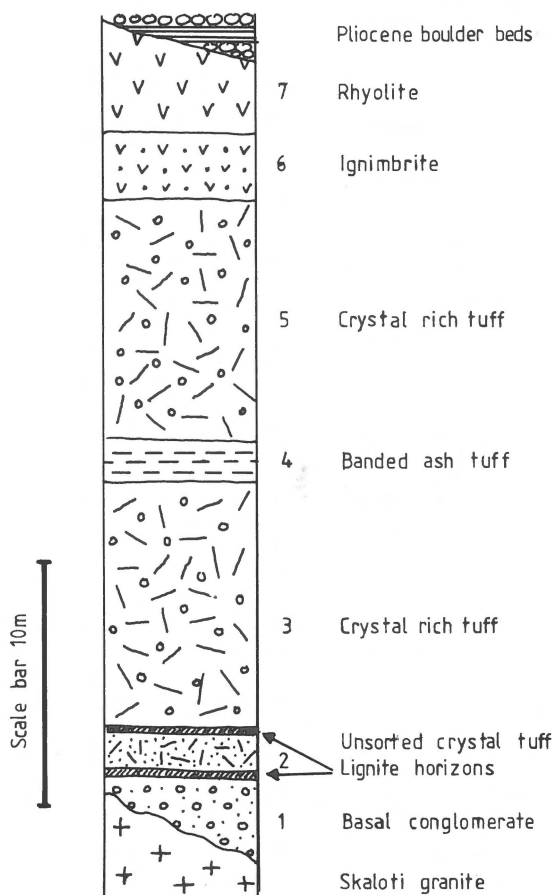


Fig. 2. Schematic profile of the volcano-sedimentary sequence from the Dipotama basin.

of extremely rapid growth in the magma chamber. Green to colourless pleochroitic amphibole, partially altered, is present, along with brownish biotite, magnetite and titanite. Crystal poor fiamme of brownish glass are present in the matrix (Fig. 3f), which comprises a debris of small phenocryst fragments. A few fragments of pyro-metamorphosed lignite are present in the lower part of the ignimbrite.

Discussion

The volcano-sedimentary basin of Dipotama

The Dipotama sequence represents a chemically

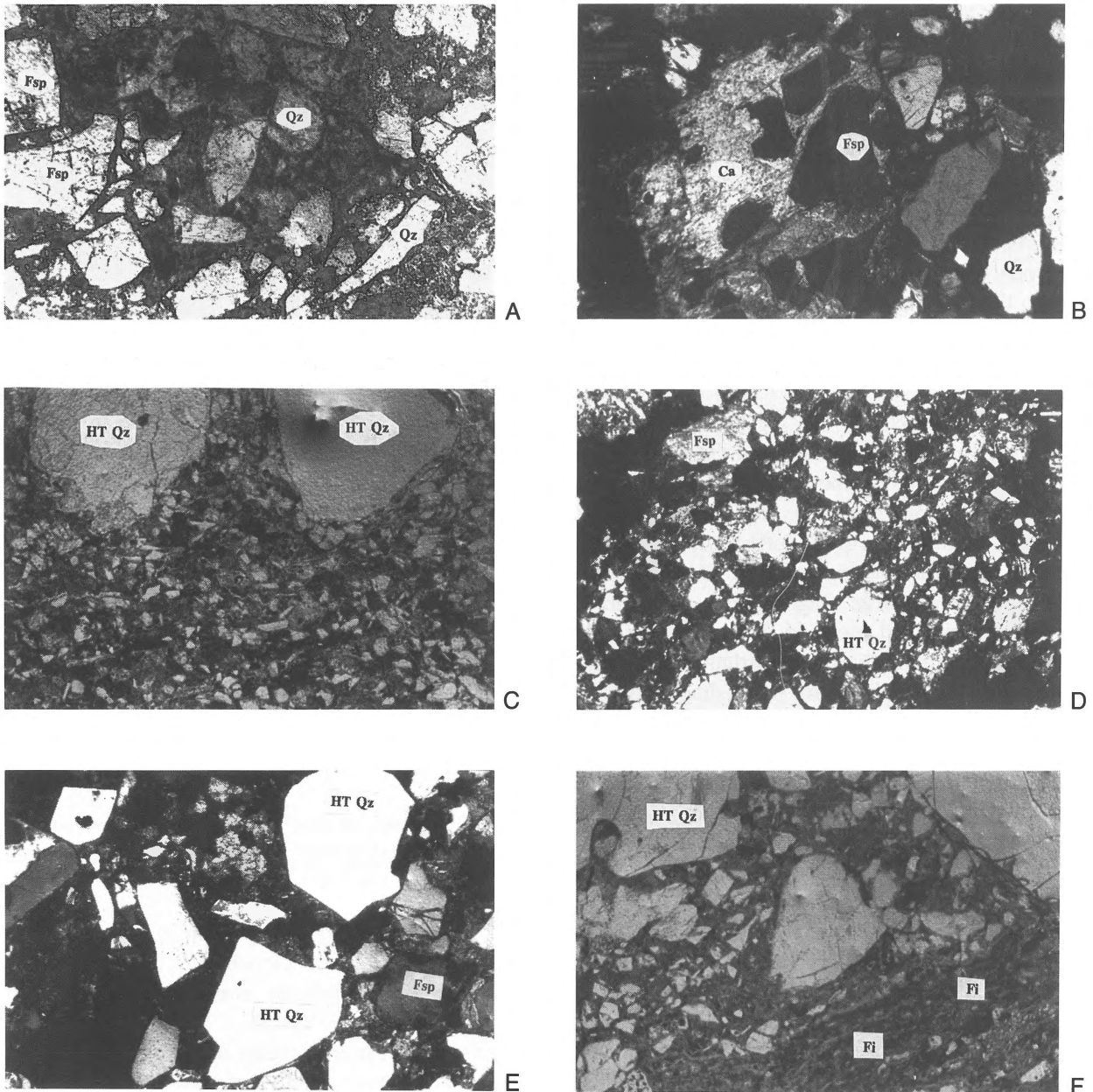


Fig. 3. A. Sample GBT 80a, 3.15 ×, pl light; Unit 2: Crystal tuff with angular quartz and feldspar in fine grained matrix. Small biotite flakes. B. Sample GBT 77a; 3.15 ×, × nic.; Unit 3: large feldspar phenocryst partially pseudomorphed by calcite in crystal tuff. C. Sample GBT 79; 1.25 ×, × nic.; Unit 4: HT quartz pseudomorphs in fine grained ash matrix with small fragments of quartz and feldspar phenocrysts. Slight parallelism of grains. D. Sample GBT 75; 1.25 ×, × nic.; Unit 5: Crystal tuff, unsorted, with some signs of reworking: HT quartz, some feldspar, and rounded grains of carbonate. E. Sample GBT 76; 1.25 ×, × nic.; Unit 5: Xenolith of coarse grained crystal tuff with angular HT quartz and feldspar with a matrix replaced by calcite. F. Sample GBT 196, 1.25 ×, pl. light; Unit 7: HT quartz phenocrysts, magmatic feldspars with glass inclusions, dark fiamme; matrix with debris of small crystal fragments in glassy matrix. Fsp: feldspar, Qz: quartz, HT Qz: high temperature quartz pseudomorphs, Ca: calcite, Fi: Fiamme.

and texturally immature volcano-sedimentary sequence preceding the main phase of felsic volcanism, but as the erosional contact demonstrates, post-dating the intrusion of the Tertiary Skaloti granite. The petrographic evidence given above argues against the interpretation of Innocenti et al. (1984) that this is purely a sedimentary sequence, though a higher sedimentary component may occur towards the deeper, more distal parts of the basin. Volcanism provided the source for the bulk of the material in the Dipotama sequence, which accumulated in a subaqueous setting, evidenced by the carbonate matrix and pebbles found in unit 3. No evidence has yet emerged to conclusively settle the question as to whether these deposits are marine or non-marine. The marble pebbles are probably derived from the erosion of the supracrustal sequence of Rhodope (Falakron marbles). As noted above, the carbonitization process which is evident in many samples examined from the volcanic rocks is often post-depositional, a result of penetration-replacement diagenesis. After erosion of supracrustal rocks, thereby exposing the granite, subsidence resulted in the formation of a basinal structure in which the lowermost, discordant basal conglomerate was deposited. No eruptive centres have been identified in the region, but the limited and generally small grain size in the sequence, with coarse grained crystal tuff present only as xenoliths, indicates that the volcanic source was not local. Some reworking of the volcanic material is evident, with grain rounding and a small amount of non-volcanic material.

The lignite horizons that overlie the basal conglomerate represent swamps or forests which were apparently engulfed by periodic volcanism, evidenced by the crystal tuff between the two lignite layers, and finally eliminated as volcanism became more persistent. While Foscolos et al. (1989) attribute the high U content of the lignite to the overlying volcanics, analyses of the volcanics do not support this (Baker, unpubl. data), whereas the underlying Skaloti granite is known to be uraniumiferous. U enrichment by leaching of the granite is thus more likely.

The transition to the > 500 m thick ignimbrite sequence (Unit 7 of Fig. 2) is abrupt, the lower part

containing a few lignite xenoliths, but with the exception of some accretionary lappili, no macroscopic changes could be seen. The pervasive hydrothermal alteration seen in the lower part of the ignimbrite produced clay alteration of feldspar and glass, pseudomorphing primary textures such as fiamme. The localized nature of the alteration, occurring along the base of the ignimbrite indicates that it is related to the extrusion of the magma across the sediment surface. The presence of lignite in the lowermost units suggests that the volcano-sedimentary sequence was deposited in shallow water. Water trapped under the bulk of the ignimbrite will have circulated within the ignimbrite as well as in the volcano-sedimentary sequence, post-consolidation alteration driven by the heat of the cooling magma. To the northeast of the quarries kaolinization of the ignimbrites has been observed, along with the formation of minor iron sulphides.

Dipotama and Tertiary basins in the eastern Mediterranean region

The Dipotama Basin is only one of a series on the Greek mainland and islands. A situation comparable to that of the Dipotama Basin in terms of depositional environment is that of the Samos Basin where lignite is intercalated with marls and limestones, overlain by rhyolitic tuffs (Stamatakis 1989) of late Miocene age (Fytikas et al. 1984). However, a significant difference is that the Samos Basin sediments are interleaved with evaporitic and diagenetic deposits including boron-rich feldspars, sulphates and zeolites, indicative of extreme desiccation (Stamatakis et al. 1989). Similar borate, sulphate and carbonate deposits in Tertiary basins are known from southern Yugoslavia (Obradovic & Jovanovic 1987) and western Anatolia (Helvacı 1984). While extensive diagenetic alteration is known to have occurred in Tertiary basin sediments from N. Greece, borates have not, as yet, been identified. Either they still have to be recognised, or their absence indicates a different degree or kind of alteration. The calcification of feldspars and the matrix to the volcano-sedimentary se-

quence at Dipotama is, however, the result of diagenetic processes.

Regional uplift and tectonic processes

The preservation of high pressure minerals and symplectic textures in metabasic rocks from eastern Rhodope has been used by Liati & Mposkos (1989) to support the idea of a rapid rate of uplift for N. Greece after the middle to late Mesozoic. The Skaloti granite has a subsolvus mineralogy requiring crystallization by at least 2 kbar. This means that after crystallization the granite must have been uplifted by about 6 km, as a thick cover of Rhodope supracrustals was removed, exposing it to erosion and the subsequent deposition of the Dipotama volcano-sedimentary sequence. The post-metamorphic Tertiary granites and volcanics are known to be approximately coeval (e.g. Eleftheriadis & Lippolt 1984, Innocenti et al. 1984), indicating the uplift must have been fairly rapid, continuing the trend initiated after the high pressure metamorphism.

Initial crustal shortening and uplift of the Rhodope region occurred following compressive continental margin arc development, in response to NE directed subduction of oceanic crust at the arc some 600 km to the SW. The relict HP assemblages present in the Rhodope zone record pressures of ca. 15 kbar (e.g. Mposkos 1989), indicating a probable total crustal thickness of 60 km. Subsequent thermal relaxation would have led to rising geotherms to produce prograde regional amphibolite facies metamorphism and the post-tectonic granites. Rapid uplift occurred in response to the convective erosion of the thermal boundary conduction layer of the lower continental lithosphere (e.g. Dewey 1988, England & Houseman 1989). This phase exhumed the Skaloti and related granites. Uplift is followed by extensional collapse as the unstable continental mass is thinned, leading to the transgressions and development of non-marine sequences in rift bounded basins of which the Dipotama Basin is an example, accompanied by voluminous ignimbrites. Extensional collapse is enhanced and continued by tensional boundary forces arising

from subduction rollback (Dewey 1981), which have turned the Aegean sea region into a N-S extensional back arc basin, whereby southward tensional forces are balanced by a southerly migration of the arc-trench system (Dewey 1981, 1988).

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Book reviews

Asquith George B. **Log evaluation of shaly sandstone reservoirs: a practical guide.** 59 pp., 37 figs. Continuing Education Course Note Ser. # 31, AAPG, Tulsa, 1990. \$14.— AAPG members (\$21.— non-members).

This slim course note is the latest offering by George Asquith on log evaluation techniques. The book is aimed primarily at explorationists having to make production evaluations in shaly sand reservoirs from wire-line data, especially those of limited experience in this field. The book may also prove useful to those in academia working on sandstone/clay distribution models when faced with additional wireline data.

Chapter 1 is an introduction into the role of clays in sandstone reservoir properties and the need for accurate bulk clay determination. This is followed by a short chapter on the nature of clay minerals. It is reassuring to learn that the essentials of such a complex research field, as it affects production geology, can be written on five pages. Chapter 3 deals with shaly sand analysis. The chapter also mentions the various techniques that should be applied to the various vintages of logs, useful when in some cases older logs are the only source of valuable data. Experienced interpreters will recognize the Dispersed Clay Method and the Simandoux and Fertl methods, while newcomers will find this a useful listing of available techniques. Chapter 4 shows how to apply the bulk volume water and porosity mapping techniques. Chapter 5 finishes the course with a series of five case studies. Admittedly all are American, they are, however, perfect examples of producing wells that would otherwise have been abandoned had not clay/shale log evaluation been carried out. A list of references, a glossary of abbreviations and critical evaluation equations, grouped together for easy reference, complete the book.

The format of the book marks a departure in style for the AAPG course notes. The text and figures are professionally typeset and are printed

on high quality semi-glossy paper. The book is spiral bound and that is my only real criticism. Even after limited use the pages began to stick and fold along the sprocket holes. The plus points, however, are that the book gives a good overview of the problems of shales and clay processes in sandstone reservoirs. At only \$14 this concise summary should find a place on the shelves of all serious explorationists.

A. Ewan Campbell (V.U., Amsterdam).

Tucker M.E., J.L. Wilson, P.D. Crevello, J.R. Sarg & J.F. Read (eds) **Carbonate platforms; facies, sequences and evolution.** 328 pp. Special Publ. 9 International Association of Sedimentologists – Blackwell, Oxford, 1990. Price: £35.00, (paperback).

The editors of this new volume in the I.A.S. Special Publication series introduce this book with the following statement: 'This collection of papers on carbonate platforms is a companion to Special Publication no. 44 on Carbonate Platform and Basin Development, published by the Society of Economic Paleontologists and Sedimentologists in 1989' (reviewed in *Geol. Mijnbouw* 69: 314; 1990).

To my opinion the only things the two books have in common are that they stem from the same 1987 S.E.P.M. Research Symposium and that, with one exception, the editors of both books are the same.

S.E.P.M. Spec. Publ. 44 is laid out into various sections, giving a clear overview of recent carbonate research. The I.A.S. Spec. Publ. 9 is exactly what the editors claim and nothing more than that: a collection of papers. Out of eleven papers contributed to this volume, eight deal with regional examples from Europe, one with the Mesozoic of Mexico and one with the Cretaceous Arabian Platform. The paper that deals with computer simulations is completely out of place in this book.

As a compilation of case studies on regional examples of carbonate platforms, the book is fine, it has a nice format and layout, and most reproductions of figures and photographs are good. A variety of aspects and controls of carbonate platforms is discussed and the subject index helps to find those. However, the title of this book suggests more.

To anyone interested in a reference book on carbonate platforms, giving an overview of recent research, I recommend S.E.P.M Spec. Publ. 44; it offers much more for a more reasonable price.

Hemmo Bosscher (V.U., Amsterdam).

Olson E.C. **The other side of the medal: a paleobiologist reflects on the art and serendipity of science.** xvi + 182 pp, 35 figs; McDonald & Woodward Publ. Co, Virginia, 1990. Price \$22.95 (cloth).

The author of this book is the distinguished UCLA paleobiologist, Olson, renowned for his teachings on, his organizing of, and his papers concerning Permian tetrapods. His narrative recounts field campaigns in Texas and museum work in Russia; Olson's friendship with two Texan cowboys and the Moscow professor and SF author I.A. Efremov, one of the philosophers of paleobiology. Olson does not present balanced pictures of research on Permian Texas or of Moscow intellectual life during the sixties. He presents us with personal, witty and sharp-sighted observations, very worthwhile for those interested in ways and opinions of paleobiologists.

The title of the book was taken from a letter by Efremov in which this metaphor is coined for the study of organism destruction and fossil preservation, taphonomy. It may be held that Olson's book preserves more than even a good fossiliferous site.

G.J. Boekschoten (V.U., Amsterdam).

Archer A.A., G.W. Luttig & I.I. Snezhko (eds) **Man's dependence on the Earth.** 216 pp. Schweizerbart, Stuttgart, 1987. Price: DM. 69.00.

This book is about the role of the Geosciences in the environment with attention of the specific issue of the impact of man on the Earth's crust, which for all practical purposes is non renewable. The purpose of the book is to provide decision makers and their advisers and planners with an insight into the many ways in which man is dependant on the Earth for survival, the consequent need to apply the principles of conservation management to it and the contribution that earth scientists can make towards this end. The book is primarily intended for non-specialists, but earth scientists unfamiliar with the subject will also benefit.

Subjects treated are: the natural systems of the environment – Man's impact on the geosphere – mineral resources – energy resources – ground-water resources – soil resources – geochemical aspects – the use of underground space – human health – geology and land-use planning – future changes, natural and man-made. The chapters have been written by scientists from the U.K., the Netherlands, France, Germany, Czechoslovakia, and from UNESCO, on the basis of papers of the 1984 UNEP/UNESCO Working Group 'Lithosphere: economic development and the environment'.

The book has been published timely with respect to the now strongly awakening environmental field.

Recommended reading for students in Earth Science.

H.E. Rondeel (V.U., Amsterdam).

Tucker M.E. & V.P. Wright (and one chapter by T. Dickson). **Carbonate sedimentology.** 482 pp. Blackwell Scient. Publ. London, 1990. Price: £ 49.50 (hardbound); £ 24.95 (paperback).

Amongst the many carbonate sedimentology oriented books that have been published lately, this textbook concentrates on giving a general overview of the current state of the art in carbonate geology.

The book contains nine chapters:

1. Carbonate sediments and limestones: constituents. This chapter gives an introduction to the

different kinds of grains in the carbonate environment. The generally used classification schemes for carbonate rocks and porosity are included.

2. Geological background to carbonate sedimentation. In the second chapter carbonate sedimentation and facies sequences of carbonate platforms, rimmed shelves and ramps are described, as well as epeiric and isolated platforms, drowned platforms and carbonate cycles present in the geological record. The last part of this chapter describes the tectonic influence on the facies development of carbonate platforms.

3. Modern carbonate platforms. Chapter three is concerned with the description of three recent examples: 1. the Bahamian platform, 2. the Florida shelf carbonates, and 3. the Trucial Coast carbonate sediments.

4. Carbonate depositional systems I: marine shallow-water and lacustrine carbonates. Chapters four and five give a lucid description of the different carbonate depositional systems. Chapter four starts with the coastal and offshore environments, followed by shelf-margin sand bodies, peritidal carbonates, lacustrine sediments and reefs. All aspects of each environment are described very accurately and are illustrated with a wide range of examples.

5. Carbonate depositional systems II: deeper-water facies of pelagic and resedimented limestones. Chapter five concentrates on pelagic carbonates with Ordovician, Devonian, Triassic and Cretaceous examples. The second part of this chapter focusses on resedimented carbonates. The processes involved are described and illustrated with the examples from the Bahamas and an extensive summary of other examples like the Middle Cambrian of the southern Rocky Mountains, the Permian Capitan Reef, the Triassic of the Dolomites a.o.

6. Carbonate mineralogy and chemistry. Crystal chemistry, trace elements and isotopes of carbonates are described in all their aspects in this chapter.

7. Diagenetic processes, products and environments. Chapter seven deals with the diagenesis of carbonates in shallow marine, meteoric and burial diagenesis.

8. Dolomites and dolomitization models. Chapter eight describes all the sedimentologic and chemical aspects of dolomites, as well as the different dolomitization models.

9. The geological record of carbonate rocks. Finally chapter nine summarizes the development of carbonate facies through time.

The book ends with an extensive reference list updated up to 1988 and an index to the figures and subjects described.

This textbook covers the wide range of the carbonate sedimentology field and is recommended as a good start for every graduate student. For the professional in industry and university it is a book in which he or she can quickly find the essentials. Two versions are offered, both reasonably priced. In general photos are reproduced well.

Two critical remarks, however, have to be made on this textbook: 1) The line drawings could be improved; some of them are too complicated, such as Fig. 4.55 (p. 155) and Fig. 5.2 (p. 231). Those figures would improve if similar space and layout were used as in Fig. 9.12 (p. 412). It's a shame that an extensive textbook like this suffers from poor lettering in some of the figures. 2) Another point of criticism is the fact that while the chapters are differentiated mainly on themes, within the chapters age or location seems to be more important than models or systems and environments. Why modern carbonate environments like the Bahamas are presented before describing the different carbonate depositional systems remains unclear.

Despite the criticism, this book will not disappoint the geologist purchasing it. It remains a question, however, whether it will replace the classical books on carbonate sedimentology like those by Wilson and Bathurst.

John J.G. Reymer, Amsterdam