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Traces of Rhyolitic-Trachytic Volcanism in the Upper Jurassic of the Southern Alps

By DANIEL BERNOULLI¹) and TJERK PETERS²)

SUMMARY

The Rosso Ammonitico Superiore (Upper Oxfordian to Tithonian) of the Venetian Alps consists mainly of red nodular pelagic limestones which have been deposited on a submerged carbonate platform surrounded by deeper basins. In this formation thin intercalations of bentonitic clays have been found at Valle del Ghelpach (Altipiano di Asiago, province of Vicenza, Italy). The $< 2\,\mu$ fraction of the clays contains mainly montmorrillonite (75–95%) and some illite (0–10%), chlorite ($<$ 5%), quartz (5–10%) and sanidine (up to 5%). In the grain sizes $> 2\,\mu$ the main constituents are sanidine, quartz and brown biotite. Additionally, some rounded grains of glass, green hornblende, weakly brown-coloured augite, apatite and tourmaline are found.

The abundance of montmorillonite in the clay and of sanidine and biotite in the silt fraction clearly indicates a volcanic origin of the clay seams, and the mineralogical composition points to a potassium-rich source. Assuming a volcanic origin of the quartz the composition of the original magma was probably rhyolitic with a tendency to trachytic. As the volcanic material is very fine grained, it might be derived from a distant source; it occurs, however, in a palaeotectonic setting which is almost identical with that of the slightly older Toarcian trachytes and Bajocian-Bathonian basalts of western Sicily and the Lessini Mountains (Southern Alps). In both areas the volcanic events may be connected with synsedimentary block-faulting.

In an appendix, a clay seam from the Domerian-Toarcian-boundary at Lábatlan, Gerecse Mountains, Hungary which must have been formed in a similar palaeogeographic situation has been analysed; in this, however, no trace of volcanic material has been found.

RIASSUNTO

La formazione del Rosso Ammonitico Superiore (Oxfordiano superiore-Titoniano) delle Prealpi Venete è composta per la massima parte di calcari rossi nodulari pelagici che si sono depositati, in un ambiente di soglia sottomarina, al di sopra di una piattaforma carbonatica sommersa e circondata da bacini più profondi. In questa formazione sono state trovate delle sottili intercalazioni di argille bentonitiche. Esse affiorano in località «Valle del Ghelpach» (Altipiano di Asiago, provincia di Vicenza). La frazione granulometrica $< 2\,\mu$ dell'argilla contiene soprattutto montmorillonite (75–95%) ed in quantità minore illite (0–10%), clorite ($<$ 5%), quarzo (5–10%) e sanidino (fino a 5%). Nella frazione $> 2\,\mu$ i costituenti prevalenti sono il sanidino, il quarzo e la biotite, mentre sono presenti pure quantità minori di granuli di vetro vulcanico, di anfibolo verde, augite, apatite e tormalino.

La prevalenza di montmorillonite nella frazione finissima e di sanidino e biotite nella frazione siltosa indicano chiaramente un'origine vulcanica delle intercalazioni argillose; la composizione mineralogica è tipica di prodotti vulcanici ricchi in potassio. Se il quarzo è di origine vulcanica, il magma originario era probabilmente di composizione riolitica con tendenza trachitica. Siccome il materiale piroclastico è a grana molto fine, il centro eruttivo doveva trovarsi a notevole distanza. Una connessione con le vulcaniti basiche delle zone ofiolitiche alpine si può escludere per ragioni petrochimiche; d'altra parte le rocce sedimentarie che contengono queste vulcaniti e le condizioni

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paleogeografiche in cui si svolsero gli accumuli, sono quasi identiche a quelle relative alle vulcaniti trachitiche e basaltiche del Lias superiore e del Dogger della Sicilia occidentale e dei Monti Lessini nel Veneto. In entrambe queste regioni gli eventi vulcanici sono connessi a movimenti tettonici distensivi.

In appendice viene analizzata la mineralogia di un'intercalazione argillosa proveniente da rocce del limite Domeriano-Toarciano delle Montagne Gerecse in Ungheria. L'argilla, che si accumulò in una situazione ambientale e paleogeografica analoga, non contiene tracce di materiale vulcanico, ed è quindi di origine detritica.

Introduction

During the Triassic the domain that later became the southern continental margin of the opening Tethyan Sea (H. P. LAUBSCHER, 1969) was the site of intense magmatic activity: the products of the Triassic volcanism are widespread over the whole realm of the "Alpine Triassic"; they are particularly well known from the Southern Alps (Dolomites, Bergamasc Alps), but have also been described from the Austro-alpine thrust-sheets, and throughout the whole of the Dinaric mountain system as far as Greece and Turkey (Porphyrite-Hornstein Formation, B. ĆIRIĆ and S. KARAMATA, 1960). During the latest Triassic and the Jurassic, the subsiding continental margin was affected by intense block-faulting (D. BERNOULLI, 1969), but indications of volcanic activity are scarse. It therefore seems that during the Jurassic volcanic activity was mainly shifted to zones of active rifting in the oceanic realm, i.e. to the ophiolite zones of the Alpine orogen. There, in fact, submarine basic extrusives have been found associated with Jurassic sediments (Diabase-Hornstein Formation, J. C. BOUSQUET, 1962; B. ĆIRIĆ and S. KARAMATA, 1960; K. GÖRLER and K. J. REUTTER, 1963; J. MERCIER, 1966), and with abyssal rocks of the ophiolite suite. In the external, ophiolite-free zones of the central Mediterranean orogenes, centers of Jurassic (Toarcian, Bajocian-Bathonian) volcanic activity are known only from western and southeastern Sicily (R. FABIANI, 1926; L. TREVISAN, 1937; F. T. KAFKA and R. B. KIRKBRIDE, 1959; J. WENDT, 1963; H. C. JENKYNS and H. S. TORRENS, 1969) whereas from the Southern Alps only remnants of Middle Jurassic volcanism have been found (H. BARS, 1965; C. STURANI, 1969) (Fig. 1). It therefore may be useful to describe in some detail newly discovered Upper Jurassic volcanic material from the Southern Alps. Like most of the previously known Lower and Middle Jurassic volcanic rocks, the Upper Jurassic bentonites are associated with pelagic red limestones of the Rosso Ammonitico facies.

Additionally a sample of a clay seam occurring in a similar sequence of red Liassic limestones in the Gerecse Mountains in Hungary was investigated, but no volcanic material was found. Since indications on the mineralogy of such clay seams in condensed pelagic sequences are very scarse, the results of our investigations are reported in an appendix.

Location of section

The volcanic material described in this paper occurs in the formation of the Rosso Ammonitico Superiore in the Altipiano di Asiago (provincia di Vicenza, Venetian Alps, Italy), in the valley of the Torrente Ghelpach, along a small road which from Ponte sul Ghelpach (Pt. 902, road Canove-Cavrari) follows the north-eastern flank of the valley [Carta d'Italia, 1:25,000, tavoletta Rotzo (F° 36 I S.E.) and Asiago (F° 37 I S.O.), Carta Geologica d'Italia, 1:100,000 (F° 36: Schio, F° 37: Bassano)].

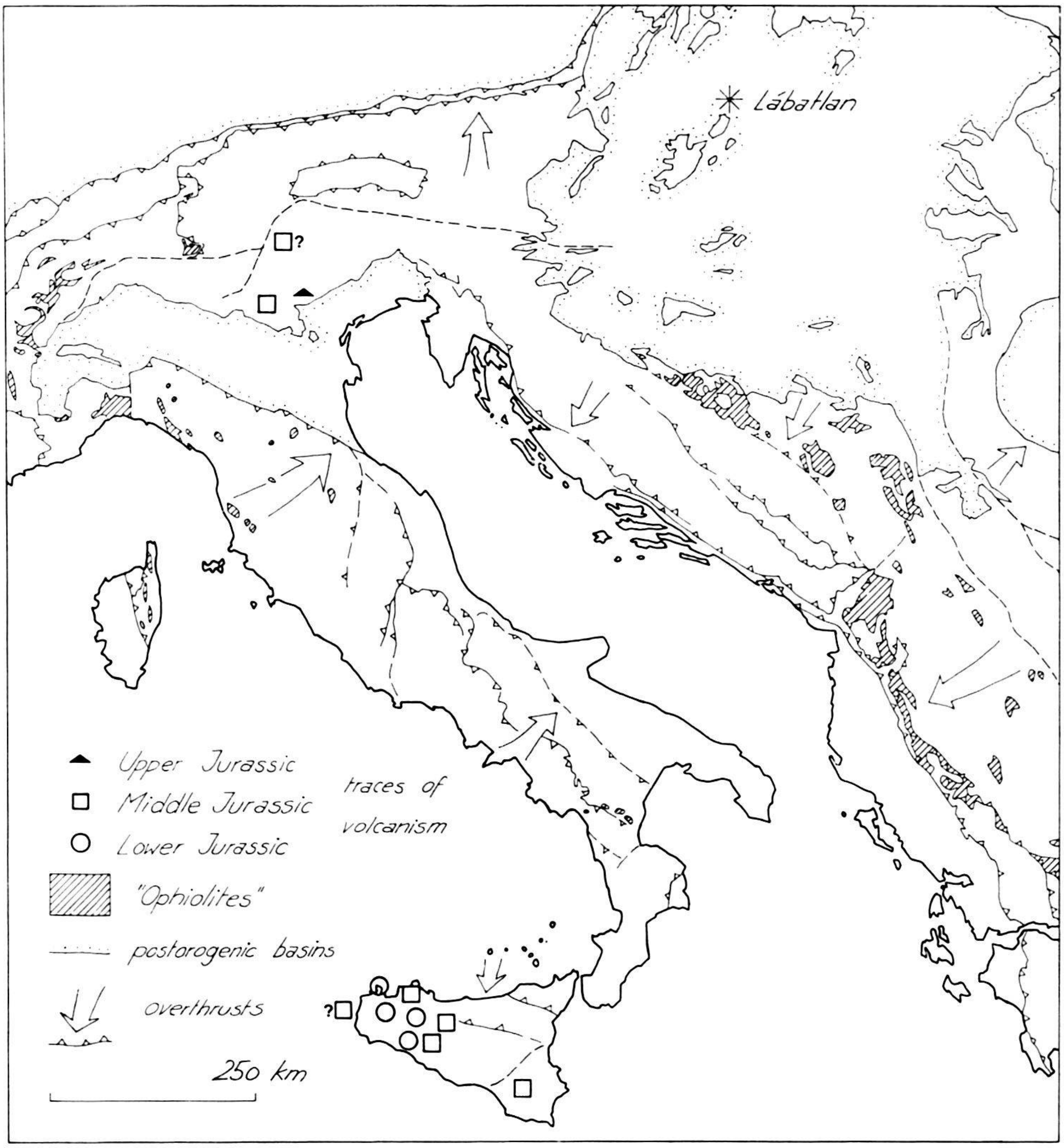

Fig. 1. Traces of Jurassic volcanism in the external zones of the central Mediterranean orogenes and present–day distribution of Alpine "ophiolites".
▲ indicates location of bentonites described in this paper (Ghelpach Valley).

The small section reproduced in Figure 3 is located along this road about 150 m southeast of Point 838 southeast of Cima Tre Pezzi (tavoletta Rotzo).

The Jurassic sequence of this locality has been described in great detail by C. STURANI (1964) from a quarry some hundred metres to the north; it is reproduced with minor alterations from his Figure 8 in our Figure 2. A detailed section of the bentonite horizons and the exact position of the samples is given in Figure 3. The bentonite horizons can be followed laterally over more than one kilometer to Ponte sul Ghelpach, where a sample for comparison has been taken (DB 3330).

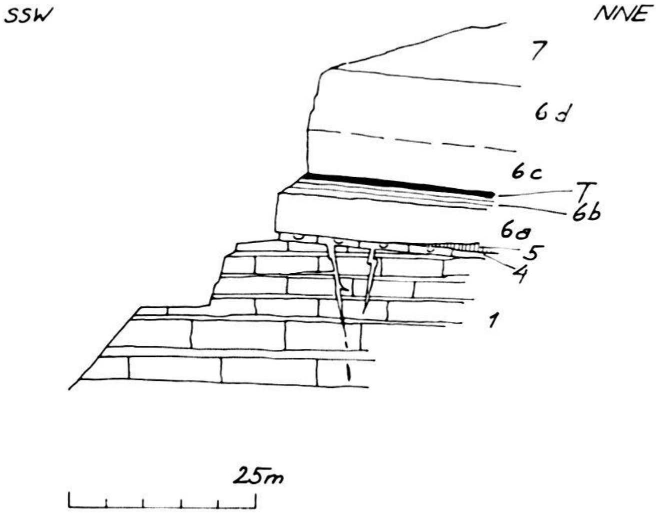

Fig. 2. The Jurassic sequence of the Ghelpach Valley, Altipiano di Asiago (provincia di Vicenza, Italy). From C. Sturani (1964), slightly modified.

7 Biancone (Maiolica), well-bedded white calcilutite with chert. Lower Cretaceous.
6 Rosso Ammonitico Superiore: Upper Jurassic (Upper Oxfordian-Tithonian).
6d 3–4 m of white, nodular calcilutite with *Ptychophylloceras ptychoicum* ("Titoniano bianco" – Berriasiano).
6c 3–4 m red, nodular calcilutite with ammonites ("Titoniano rosso").
T 0.25 m, alternation of red and white, plastic bentonitic clays and white to pink finely "pelleted" calcilutites-calcisiltites. Detailed section: Fig. 3.
6b 0.30 m white, flaser-textured calcilutite.
2 m thin-bedded, nodular calcilutite with belemnites.
According to C. Sturani (1964): Kimmeridgian.
6a 6–10 m red nodular calcilutites with pelagic lamellibranchs.
Hard-ground.
5 Rosso Ammonitico Inferiore: compact, red limestone with *Phylloceras* sp., only locally present, thickness up to some ten centimetres. If present, the upper surface of the Ammonitico Rosso Inferiore is constituted by a ferromanganiferous hard-ground, which corresponds to a stratigraphic gap comprising the stages between the Upper Bajocian and the Upper Oxfordian (C. Sturani, 1964, Fig. 6). Upper Bajocian.
4 0–1.50 m Lumachella a "*Posidonia*" *alpina:* breccia composed of angular components of the underlying Calcari Grigi, fragmented *in situ* and cemented by, and passing upwards into, skeletal limestones ("*Posidonia*" (*Bositra*)). Bajocian p.p. (zones from *sauzei* to *subfurcatum*).
1 Calcari Grigi: thick-bedded, grey, mainly skeletal limestones with interbedded layers of grey to green marls (brachiopods, "lithiotids", *Orbitopsella*): Middle Liassic.

Stratigraphy and palaeogeographic situation

The formation of the Rosso Ammonitico Superiore (Upper Jurassic) is characteristic for the palaeogeographic realm of the Trento zone (for the stratigraphic sequence of the Trento zone see Figure 2 and J. Aubouin, 1963; C. Sturani, 1964). In the Lower Jurassic this zone was occupied by a Bahamian-type carbonate platform, which was flanked by two deeper marine basins in the west (Lombardian zone) and in the east (Belluno zone). During the Lower and Middle Liassic conditions of restricted water circulation prevailed over the internal parts of the platform (Calcari Grigi), whereas in the Upper Liassic faunal composition and lithology indicate a strong increase of open marine influence (San Vigilio Oolites, Calcari Gialli, Bilobata Beds).

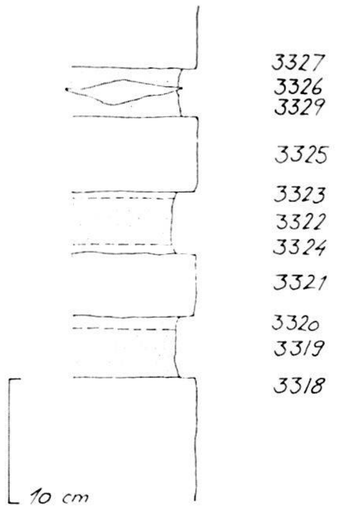

Fig. 3. Detailed section of bentonite horizons, Rosso Ammonitico Superiore, Upper Jurassic, Ghelpach Valley.

From top to bottom:

28 cm	white, finely "pelleted" calcisiltite (pelsparite; micritized radiolaria, crinoid ossicles, aptychi). Traces of fresh sanidine, angular quartz and brownish-green biotite. DB 3327.
3–5 cm	red and white bentonitic clay (DB 3329) with lenses of white finely "pelleted" calcisiltite (pelsparite, ? micritized radiolaria) to calcilutite with various amounts of biota (radiolaria, crinoid ossicles, aptychi) and traces of sanidine. DB 3326.
6–7 cm	white, finely "pelleted" calcisiltite (micritized and calzitized radiolaria), overlain by flaser-textured fine bioclastic calcarenite (radiolaria, crinoid ossicles, aptychi). Sporadically sanidine and a trace of green-brown biotite. DB 3325.
0.5 cm	white bentonitic clay. DB 3323.
4 cm	red bentonitic clay. DB 3322.
0.5 cm	white bentonitic clay. DB 3324.
5 cm	white, slightly pelleted bioclastic calcisiltite to fine calcarenite (biomicrite; radiolaria, crinoid ossicles, aptychi, belemnites). Some partly fresh sanidine, angular quartz grains and brown biotite. DB 3321.
1 cm	white bentonitic clay. DB 3320.
4 cm	red bentonitic clay. DB 3319.
ca. 30 cm	white to red, flaser-textured fine biomicrite (radiolaria, crinoid ossicles). DB 3318.

From the Middle Jurassic onwards, production and sedimentation of shallow-water carbonates did not keep up with subsidence and the platform was submerged; it persisted, however, as a submarine topographical high on which only small amounts of mainly pelagic sediments accumulated (Lumachella a "*Posidonia*" *alpina*, Rosso Ammonitico Inferiore, Rosso Ammonitico Superiore). The crinoidal rocks and washed skeletal limestones of the Lumachella a "*Posidonia*" *alpina* reflect a transitional stage during the sinking of the platform, they are open marine deposits which formed on a current-swept, submerged high but not necessairely at great depth, possibly even within the photic zone (C. STURANI, 1967). The sediments of the Rosso Ammonitico are essentially pelagic, but their absolute bathymetry can not be established with certainty. The small amounts of terrigenous clays, however, indicate that the Rosso Ammonitico limestones have been deposited on a submerged platform sheltered from terrigenous influx by surrounding deeper basins and the different lithologies seem to be related to different stages of bathymetry, bottom morphology and to different sedimentation/erosion ratios on the subsiding plateau (for details see R. HOLLMANN, 1964; C. STURANI, 1969, and H. C. JENKYNS and H. S. TORRENS, 1969): the entire pelagic sequence is characterized by numerous stratigraphic gaps, hard-grounds and by sedimentary dykes and sills filled with sediments derived from younger formations (C. STURANI, 1964, 1967, 1969; A. CASTELLARIN, 1965). From the Lower Cretaceous onwards, relatively uniform conditions of sedimentation are indicated by the white calcilutites of the Biancone (Maiolica) Formation, but occasional non-sequences in the western Trento zone indicate local persistence of current-swept highs during the Cretaceous.

Mineralogy

Experimental

Samples were dispersed in 0.01 n ammonia and shaken for several days. Fractions $> 105\ \mu$ and 63–105 μ were obtained by wet sieving. The fraction $< 2\ \mu$ was separated by sedimentation. The clay fraction was freed of calcite with 2n HCl, saturated with Ca^{2+} and X-rayed in a Phillips-diffractometer and a Guinier camera.

The coarser grain sizes were decalcified with citric acid. Because of the small grain sizes that had to be used, the heavy minerals were separated in a centrifuge. The light and heavy minerals were investigated optically and by X-ray diffraction.

Results

Clay fraction

In all the investigated samples *montmorillonite* is by far the most important clay mineral (Table 1). The succession of the basal reflections at 16.9 Å, 8.6 Å, 5.6 Å, 4.3 Å, 3.4 Å and 2.8 Å in samples saturated in ethylene glycol; at 14.9 Å, 5.1 Å and 3.1 Å, in air dry samples and at 9.5 Å, 4.75 Å and 3.16 Å in samples fired at 550 °C are characteristic for montmorillonite. According to its (060)-reflection at 1.501 Å this montmorillonite is dioctahedral. In Figure 4 a diffractometer-diagram of an almost pure montmorillonite sample is presented (DB 3322). The electron-microscope pictures show very thin plates with irregular boundaries (Fig. 5). Rolled edges which are common for montmorillonite flakes were not observed.

Some samples show in the air dry state a basal reflection of *illite* at 10 Å which does not change its position on glycollation. In the diffractometer-diagram of sample

Table 1. Mineralogical composition of decalcified fractions $< 2\ \mu$ of the volcanic layers in the Rosso Ammonitico Superiore, Ghelpach Valley.

Sample Nr.	Montmorillonite	Illite	Chlorite	Quartz	Sanidine	Hematite
DB 3319	95	tr	-	tr	tr	+
3320	75	10	<5	5	5	-
3322	95	-	-	tr	tr	+
3323	85	5	<5	5	<5	-
3324	90	<5	-	5	<5	-
3329	75	10	<5	5-10	5	+
3330	90	<5	<5	tr	tr	+

tr = trace

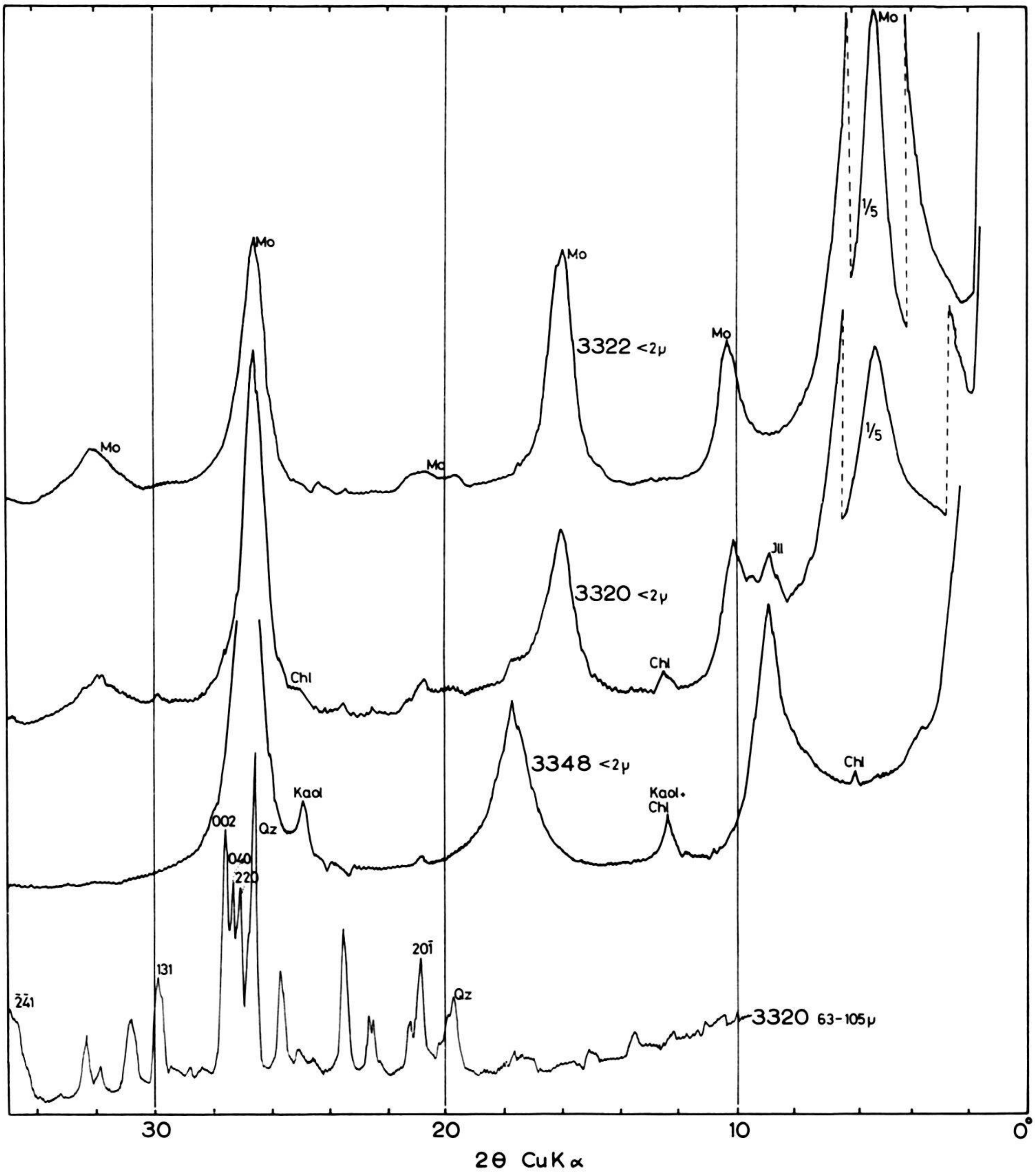

Fig. 4. X-ray diffraction patterns of glycollated clay fractions of samples DB 3320, 3322 (Rosso Ammonitico Superiore, Upper Jurassic, Ghelpach Valley, Italy) and DB 3348 (Domerian-Toarcian boundary, Lábatlan, Hungary) and of decalcified sanidine-rich silt fraction of sample DB 3320 (Rosso Ammonitico Superiore, Ghelpach Valley).

DB 3320 in Figure 4 this illite reflection can be observed. The small amount present makes it impossible to determine whether this illite is dioctahedral or trioctahedral. The presence of a lot of biotite and the absence of muscovite in the larger grain sizes, however, make a trioctahedral character of the illite more probable. Some *chlorite* is present in the samples that contain illite. In ethylene glycol saturated samples weak chlorite reflections at 7.1 Å and 3.54 Å are still present, and after firing at 550 °C a

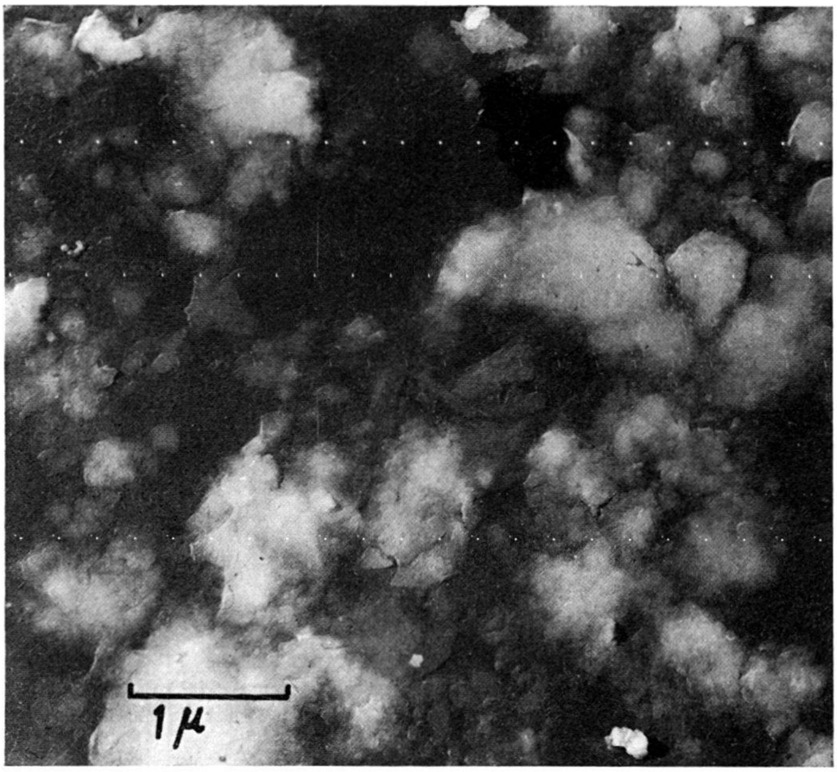

Fig. 5. Electron micrograph of decalcified clay fraction of a bentonite from the Rosso Ammonitico Superiore. Ghelpach Valley. Cr-shadowed.

reflection at 13.8 Å is sometimes visible. Minor amounts of *quartz* and *alkali felspar* are present in the clay fractions. In some samples this felspar could be determined more precisely: it is a sanidine with an approximate composition of $Or_{70}Ab_{30}$. Red coloured samples contain minor amounts of haematite.

The chemical composition of the (not decalcified) clay-fraction is given in Table 2. The rather high potassium content is due to the presence of sanidine which occurs even in the finest fraction. A large part of the calcium is bound up as carbonate (calcite) which could not be determined quantitatively due to paucity of sample material. On the whole the analysis indicate a montmorillonite s. str. - rich member within the montmorillonite s. str. - beidellite series for the composition of the main clay mineral.

Composition of the non clay grain sizes

The samples investigated are very fine grained so that only minor amounts of the coarse fractions were obtained after separation. *Sanidine* is the main constituent of the decalcified coarser grain sizes. Optically this sanidine was recognized by its small optic angle. The 131 reflections in the X-ray pattern (Fig. 4) indicate a triclinity of zero and from the position of the $20\bar{1}$ reflection at about 21° 2θ a composition of about $Or_{70}Ab_{30}$ can be calculated with the help of the determinative curves of O. F. Tuttle and N. L. Bowen (1958). *Quartz* is present in amounts slightly less than sanidine. Appreciable amounts of brown *biotite* occur in all samples and constitute most of the heavy mineral fraction. Other detected heavy minerals are brown glass in rounded grains, green hornblende, weakly brown coloured augite, apatite, tourmaline and brownish? epidote.

Table 2. Chemical analyses of two clay fractions (< 2 μ) of bentonite layers. Rosso Ammonitico Superiore, Ghelpach Valley.

	DB 3320	DB 3329
SiO_2	48, 38	50, 50
Al_2O_3	16, 50	17, 40
Fe_2O_3	2, 20	5, 25
CaO	9, 26	5, 05
MgO	3, 0	2, 76
Na_2O	-	-
K_2O	3, 17	3, 15
Ignition loss (H_2O^-, H_2O^+, CO_2)	19, 52	17, 2
Total	102, 03	1o1, 31

Analyst: CH. RÜTHER

Discussion

The abundance of montmorillonite in the clay fractions and of sanidine and biotite in the coarser grain sizes, together with the presence of glass strongly indicates volcanic origin for the non-carbonate material of the investigated samples from the Rosso Ammonitico Superiore. In non-volcanic marine clays muscovite and only very sparse biotite is encountered.

The predominance of sanidine and biotite points to a very potassium-rich magma from which the tuffs originated. As the amount of other mafic minerals like augite and hornblende is almost negligible and the composition of the montmorillonite (which represents more or less the composition of the original glass fragments) shows little magnesium and iron, the tuffs cannot have been a product of basic volcanism. In the coarse grain sizes the ratio of sanidine to quartz is about 2 : 1, favouring a rhyolitic composition for the extruded material. However, part or all of the quartz present might be detrital, in which case a more trachytic composition of the magma must be deduced. Nevertheless, as some of the quartz grains observed in thin-sections are about the same size and as angular as the accompanying sanidine grains, a volcanic origin for part of the quartz seems very likely. Thus the original magma was probably rhyolitic with a tendency towards trachytic.

Up till now no *Upper Jurassic* lavas have been found in the Southern Alps or in other regions in the external (ophiolite-free) zones of the central Mediterranean orogenes. As the material is very fine grained, the source was probably at some distance (see A. HALLAM and B. W. SELLWOOD, 1968 and references therein). A connection with Upper Jurassic volcanic rocks of the ophiolite zones is, however, highly improbable because of the high potassium and low sodium content of the bentonites from the Southern Alps. Mineralogically they best compare with trachytic fragments that occur in Toarcian iron pisolites of western Sicily (H. C. JENKYNS, 1970), and with regard to their palaeogeographic setting, with basaltic lavas and tuffs occurring in the Bajocian-Bathonian of the Southern Alps (C. STURANI, 1969) and of western Sicily (R. FABIANI, 1926 and others).

Traces of Middle Jurassic volcanic activity have been reported in the Southern Alps from the Val di Non area north-west of Trento and from the Lessini Mountains north of Verona. In the Val di Non area H. BARS (1965) found three intercalations of marly clays in limestones to which he assigned an Upper Dogger age; they contained pyrite, augite, quartz, gypsum and volcanic glass and were interpreted by BARS as tuffites. A more detailed analysis, however, was not made and no identification of the clay minerals was attempted; furthermore the exact age within the Jurassic sequence has not been established on a biostratigraphical basis. In the Monti Lessini C. STURANI (1969) has recently found remnants of Middle Jurassic volcanism in the Rosso Ammonitico Inferiore, dated by ammonites as Bajocian-Bathonian. The volcanic material is contained in a lens within pelagic deposits. It comprises more or less weathered angular fragments of volcanic glass with a vesicular or fluidal structure, crystals of olivine and pyroxene replaced by clay minerals, ferruginous material or calcite and very rare preserved crystals of plagioclase, sanidine and apatite. The size of these fragment can range up to 3 cm across. The pyroclastic deposit is interpreted as a cineritic tuff of basaltic composition deposited in a marine environment.

In western Sicily the lavas and tuffs are associated with condensed limestone sequences capping the drowned Lower/Middle Liassic carbonate platforms (H. C. JENKYNS and H. S. TORRENS, 1969). In the Toarcian mainly trachytic rocks are present (sanidine trachytes in Toarcian iron-pisolites of different localities (H. C. JENKYNS, 1970); hornblende-trachytes of possible Toarcian age at Monte Bonifato (H. C. JENKYNS and H. S. TORRENS, 1969, cf. J. WENDT, 1963), whereas the Middle Jurassic volcanics are of basaltic composition (R. FABIANI, 1926; L. TREVISAN, 1937). In both cases the volcanic events may be correlated with phases of distensive tectonic movements as evidenced by synsedimentary faults and neptunian dykes (J. WENDT, 1965, 1969; H. C. JENKYNS and H. S. TORRENS, 1969). The Toarcian phase, in fact, corresponds roughly to the time of disintegration of the carbonate platform, whereas during the Middle Jurassic the differentially subsiding blocks evolved into seamounts and local basins – and a further correlation between tectonism and volcanism can be assumed. A similar palaeotectonic evolution can be reconstructed for the Trento zone of the Southern Alps (C. STURANI, 1967, 1969); here, however, the volcanic activity apparently persisted into the Upper Jurassic.

From our present state of knowledge it seems that the Jurassic volcanites in the *external* zones of the central Mediterranean orogenes are connected with structural highs (western Sicily, Trento zone), whereas in the deeper basins volcanic rocks are generally absent (e.g. in the Lombardian zone). Examples of the latter could be found in the basaltic rocks of presumed Jurassic age in the western Madonie Mountains (central Sicily, P. SCHMIDT DI FRIEDBERG et al., 1959) and in the Pindos zone of

Greece, if these are not derived from a more oceanic realm. The lack of volcanic remnants in basins may be due partly to the fact that bentonites will be most obvious in a condensed limestone "seamount" facies where the clay seams will weather back – than in the marly basinal facies where they will blend into the host rock. On the other hand, no volcanic activity has been found associated with the huge Jurassic fault scarps bounding the strongly subsiding Jurassic basins (Lugano Line: D. Bernoulli, 1964; Ballino Line: A. Castellarin, personal communication) and therefore the magmatic activity seems to be associated with relatively small-scale structural weaknesses within the larger "seamount" plateau areas rather than with their faulted edges.

Appendix

An analysis of a clay seam from the Liassic of the Gerecse Mountains, Hungary

In Hungary the Jurassic sequences of the Gerecse and Bakony Mountains indicate a palaeotectonic evolution which was very similar to that of the Trento zone of the Southern Alps (J. Aubouin, 1963, 1964; C. Sturani, 1964, 1967), of western Sicily (J. Wendt, 1963, 1969; H. C. Jenkyns and H. S. Torrens, 1969) and of the Umbrian-Marchean Apennines (D. Bernoulli, 1969). During the Lower Liassic, the carbonate platform which occupied the region was submerged and a differentiation into persisting submarine highs with reduced and condensed pelagic sedimentation ("seamounts") and local basins with continuous deposition took place. The disintegration and sinking of the former platform was most probably connected with synsedimentary block-faulting which in turn might have been associated with synchroneous igneous activity, as could be suggested by trachytic rocks associated with Liassic Adnet Limestones (Rosso Ammonitico) in the East Carpathians (D. Patrulius, 1960). However, until now no trace of Jurassic volcanic activity has been found in Hungary (G. Pantò, 1961). In order to test the possibility of volcanic events in this area during the Jurassic a sample from a clay seam in a stratigraphic setting comparable to that one of the Venetian bentonites has been investigated. Although no material of certain volcanic origin has been found, the results are reported here, as information on the clay mineralogy of Tethyan Jurassic sequences are scarse.

The sample investigated (DB 3348) comes from a clay seam intercalated between Middle and Upper Liassic pelagic limestones from Tölgyháty quarry near Lábatlan, Gerecse Mountains, Hungary. The stratigraphic sequence of this quarry has been described in detail by G. Vigh (1961) and J. Fülöp (1969, Fig. 10). The upper surface of the Middle Liassic pelagic limestones is coated by a black ferromanganese crust, a few some centimeters thick, which is overlain by some 50 cm of dark grey, yellowish weathering shale (J. Fülöp, 1969, Fig. 10, bed 4). The shale is in turn overlain by 1.5 to 2 metres of marly nodular limestones with abundant ammonites of Toarcian age (Rosso Ammonitico). The remaining Jurassic sequence comprises nodular and platy limestones of Toarcian to Bajocian age, thin radiolarites of the Bathonian-Callovian, intraformational breccias of the Oxfordian and nodular limestones of the Kimmeridgian-Tithonian.

Although the clay sample is very fine grained and disintegrates easily in water, it contains no detectable amounts of montmorillonite. The sample consists mainly of dioctahedral illite of 1 Md-type structure. Some kaolinite could be identified from

X-ray reflections at 7.1 Å; 3.57 Å and 1.48 Å. In Figure 4 a diffractometer diagram is given. A very small quantity of chlorite is also present as a reflection at 13.6 Å appeared after firing at 550 °C. The clay fraction is thus composed of:

Illite	80–85%
Chlorite	< 5%
Kaolinite	10%
Quartz	5%

Quartz is by far the most abundant mineral in the coarse grain sizes. Besides quartz and aggregates of clay minerals only trace amounts of albite were detected. Under the microscope green coloured aggregates, similar to glauconite, were observed.

No evidence of volcanic material was found, but the fine-grained illite might have originated from montmorillomite by aggradation in a potassium-rich environment, similar to many metabentonites. This hypothesis, however, is not likely as no volcanic heavy minerals have been detected. The clay mineral association of mainly illite, some kaolinite and chlorite is common for marine dark coloured shales and generally of detrital origin and in fact the Adnet Limestone (Middle Liassic) of the northern calcareous Alps contains mainly illite and some kaolinite which must be detrital (A. HALLAM, 1967). Since similar mineral assemblages composed of mixedlayer minerals, illite, kaolinite, quartz and some albite have been determined in the Upper Jurassic limestones at Lábatlan (W. M. BAUSCH, 1969) it seems that a continuous influx of terrigenous clay minerals has been superimposed on the pelagic sedimentation, leading in the case of interrupted carbonate deposition to enrichment in local clay seams. Interruption of carbonate sedimentation at the Domerian-Toarcian-boundary at Lábatlan is indicated by a ferromanganese hard-ground; however, it is questionable, whether the absence of carbonate deposition is the only factor responsable for the deposition and preservation of such a thick clay seam. At any rate it is difficult to explain why terrigenous clays should be preserved on a current-swept seamount (B. C. HEEZEN and C. HOLLISTER, 1964), whereas fine carbonate material should be carried away.

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REFERENCES

AUBOUIN, J. (1963): *Essai sur la paléogéographie post-triasique et l'évolution secondaire et tertiaire du versant sud des Alpes orientales.* Bull. Soc. Géol. France (7), *5*, 730–766.

– (1964): *Réflexions sur le faciès "Ammonitico Rosso".* Bull. Soc. Géol. France (7), *6*, 475–501.

BARS, H. (1965): *Geologie des südlichen Nonsberges und der angrenzenden Gebiete.* Veröff. Mus. Ferdinandeum *45*, 5–60.

BAUSCH, W. M. (1969): *Tonmineralprovinzen in Malmkalken.* Manuskript.

BERNOULLI, D. (1964): *Zur Geologie des Monte Generoso (Lombardische Alpen).* Beitr. geol. Karte Schweiz (NF) *118*, 134 pp.

– (1969): *Redeposited Pelagic Sediments in the Jurassic of the Central Mediterranean Area.* Preprint. Colloquium on Mediterranean Jurassic Stratigraphy, Budapest, 1969, to be published in Ann. Inst. Geol. Publ. Hung.

BOUSQUET, J. C. (1962): *Âge de la série des diabases-porphyrites (roches vertes du flysch calabro-lucanien; Italie méridionale).* Bull. Soc. Géol. France (7), *4*, 712–718.

CASTELLARIN, A. (1965): *Filoni sedimentari nel Giurese di Loppio (Trentino meridionale).* Giorn. Geol. *33*/2, 527–546.

ĆIRIĆ, B. & KARAMATA, S. (1960): *L'évolution du magmatisme dans le géosynclinal dinarique au Mésozoïque et au Cénozoïque.* Bull. Soc. Géol. France (7), *2*, 376–380.

FABIANI, R. (1926): *Scoperta di un apparato eruttivo del Giurese medio in Sicilia.* Boll. Assoc. Miner. Siciliana *2*, 3–12.

FÜLÖP, J. (1969): *Excursion Guide. Geology of the Transdanubian Central, Mecsek and Villányi Mountains.* Coll. Mediterranean Jurassic Stratigr. Budapest, 1969.

GÖRLER, K. & REUTTER, K. J. (1963): *Die stratigraphische Einordnung der Ophiolithe des Nordapennins.* Geol. Rdsch. *53*, 358–375.

HALLAM, A. (1967): *Sedimentology and Palaeogeographic Significance of Certain Red Limestones and Associated Beds in the Lias of the Alpine Region.* Scott. J. Geol. *3*, 195–220.

– & SELLWOOD, B. W. (1968): *Origin of Fuller's Earth in the Mesozoic of Southern England.* Nature *220*/5173, 1193–1195.

HEEZEN, B. C. & HOLLISTER, C. (1964): *Deep-Sea Current Evidence from Abyssal Sediments.* Marine Geol. *1*, 141–174.

HOLLMANN, R. (1964): *Subsolutions-Fragmente.* N. Jb. Geol. Paläont., Abh. *119*, 22–82.

JENKYNS, H. C. & TORRENS, H. S. (1969): *Palaeogeographic Evolution of Jurassic Seamounts in Western Sicily.* Preprint. Colloquium on Mediterranean Jurassic Stratigraphy, Budapest 1969, to be published in Ann. Inst. Geol. Publ. Hung.

JENKYNS, H. C. (1970): *Submarine Volcanism and the Toarcian Iron Pisolites of Western Sicily.* Eclogae geol. Helv. *63*, 549–572.

KAFKA, F. T. & KIRKBRIDE, R. K. (1959): *The Ragusa Oil Field, Sicily.* Proc. 5th World Petrol. Congr., Sect. I: 233–257.

LAUBSCHER, H. P. (1969): *Mountain Building.* Tectonophysics *7*, 551–563.

MERCIER, J. (1966): *Paléogéographie, orogenèse, métamorphisme et magmatisme des zones internes des Hellénides en Macédoine (Grèce): vue d'ensemble.* Bull. Soc. Géol. France (7), *8*, 1020–1049.

PANTÒ, G. (1961): *Le magmatisme mésozoïque en Hongrie.* Ann. Inst. Geol. Publ. Hung. *49*, 979–997.

PATRULIUS, D. (1960): *La couverture mésozoïque des massif cristallins des Carpates orientales.* Ann. Inst. Geol. Publ. Hung. *49*, 123–154.

SCHMIDT DI FRIEDBERG, P., BARBIERI, F. & GIANNINI, G. (1959): *La geologia del gruppo montuoso delle Madonie.* Boll. Serv. Geol. Ital. *81*/1, 73–140.

STURANI, C. (1964): *La successione delle faune ad ammoniti nelle formazioni medio-giurassiche delle Prealpi venete occidentali.* Mem. Ist. Geol. Mineral. Univ. Padova *24*, 1–63.

– (1967): *Reflexions sur les faciès lumachelliques du Dogger mésogéen ("Lumachelle à Posidonia alpina" auctt.).* Boll. Soc. Geol. Ital. *86*, 445–467.

– (1969): *Intercalazione di Vulcaniti Medio-Giurassiche nel "Rosso Ammonitico" dei Lessini veronesi.* Boll. Soc. Geol. Ital. *88*, 589–601.

TUTTLE, O. F. & BOWEN, N. L. (1958): *Origin of Granite in the Light of Experimental Studies in the System* $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2–H_2O. Geol. Soc. Amer., Mem. *74*, 153 pp.

TREVISAN, L. (1937): *Scoperta di formazioni basaltiche e piroclastiche presso Vicari (Palermo) e osservazioni sui fossili baiociani contenuti nei tufi.* Boll. Soc. Geol. Ital. *56*, 441–452.

TRÜMPY, R. (1960): *Paleotectonic Evolution of the Central and Western Alps.* Bull. Geol. Soc. Amer. *71*, 843–908.

VIGH, G. (1961): *Problèmes de faciès des sédiments jurassiques de la Montagne Gerecse.* Ann. Inst. Publ. Hung. *49*, 591–598.

WENDT, J. (1963): *Stratigraphisch-paläontologische Untersuchungen im Dogger Westsiziliens.* Boll. Soc. Paleont. Ital. *2*, 57–145.

– (1965): *Synsedimentäre Bruchtektonik im Jura Westsiziliens.* N. Jb. Geol. Paläont., Mh. *1965*, 286–311.

– (1969): *Die stratigraphisch-paläogeographische Entwicklung des Jura in Westsizilien.* Geol. Rdsch. *58*, 735–755.