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NEW ASPECTS OF THE QUATERNARY COASTAL GEOMORPHOLOGY

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ABSTRACT : On the way towards a world-wide sea-level stratigraphy the introduction of chronometric dating techniques brought a revolution and showed the limits of all earlier approaches, i.e. the altimetric, bio- and lithostratigraphic ones. A modern attempt is the correlation between the Quaternary shorelines and the paleotemperature-curves of the oceans.

An application of this method is demonstrated in this paper for the littoral lowland of Metaponto (Southern Italy), where 11 stepped uplifted marine accumulation terraces can be found. Their research furthermore leads to the suggestion for a new terminology and the discussion of the general development of marine accumulation terraces. Finally a model for the glacioeustatic sea-level fluctuations interfering with tectonic uplift plus its application on a typical profile are presented.

HISTORICAL PERSPECTIVES OF SHORELINE STUDIES

Raised beaches and fossil shorelines are found in many Mediterranean regions because of their young tectonic uplift. So the Mediterranean area – especially Italy – is the historical one where many typical sites and profiles of the marine Quaternary have been studied. The classical names for the marine transgressions and the terraces created by them – like the Calabrian, Sicilian, Milazzian, Tyrrhenian and Versilian – bear an obvious witness for that fact.

The history of the Quaternary sea-level stratigraphy started with the attempt of an altimetric correlation of the different fossil coasts. It was followed by the faunal approach, trying to define the Pleistocene stages by indicator fossils like the Senegal fauna *Strombus bubonius* for the Tyrrhenian terraces. In some places the interdigitation of marine and continental deposits was another attempt of differentiating Quaternary beaches.

But neither the altimetric nor the bio- nor the lithostratigraphic approaches were sufficient for the construction of a global Quaternary sea-level stratigraphy:

1. As the Mediterranean basin is tectonically unstable a coordination of the different sea-levels from their altitude alone leads to wrong conclusions (see HEY 1971; 1978). In Italy e.g., the Calabrian terrace is

located 1,400 m a.s.l. on the Aspromonte (Calabria), 750 m at the foot of the Etna-vulcano (Sicily) and only 400 m near Salerno (south of Naples).

2. A closer look at the biostratigraphic approach in what were believed typical sites showed that some raised beaches and the therewith connected transgressions were badly defined. According to RUGGIERI/SPROVIERI (1977) neither the Sicilian nor the Milazzian fauna is linked to any shoreline. So one has to find new interpretations for these stages.

3. The lithostratigraphic approach, i.e. the interdigitation of marine and continental deposits, is only helpful if the stratigraphical position and definition of the terrestrial sediments are doubtlessly clear, an assumption which is often hard to fullfill.

A NEW ERA THROUGH ABSOLUTE DATINGS

The key to a new era in the Quaternary sea-level research was the application of chronometric dating techniques.

STEARNS/THURBER (1965) were the pioneers by ^{230}Th / ^{234}U-dating marine fossils from the Mediterranean and Moroccan littorals. Since then innumerable series of absolute dates have been published. For the late Pleistocene the presently favoured methods are the ^{230}Th / ^{234}U, ESR (electron spin resonance) and TL (thermoluminescence) dating techniques (for information about these methods and their application see e.g. GEYH 1980, HACKENS 1983, HENNIG/GRON 1983). The preferred object are mollusca, corals, deep-sea sediments, eolianites, beachrocks and secondary carbonates. The radiocarbon method done on mollusca is contested because recrystallization and even slight contamination give too young ages. A cross-check with other methods showed for instance that the presumed intra-Wurmian high sea-level about 30,000 b.p., based on ^{14}C-dated mollusca, had to be dropped (see e.g. BROCKNER 1980, 148 ff.).

Further progress came through the global perspective, when ^{230}Th/^{234}U-dates were reported from stepped coral-reefs in Barbados, Bermuda and New Guinea (cf. BUTZER 1983). By this one also tried to find the absolute altitudes of the Pleistocene glacio-eustatic transgressions, a task which is not at all finished yet.

New aspects arose from the deep-sea research on long sediment cores which led to the development of paleotemperature-curves for the oceans derived from $^{18}O/^{16}O$ isotopic ratios. First published by EMILIANI (1955) the results were later improved by SHACKLETON/OPDYKE (1973) and EMILIANI/SHACKLETON (1974) (see Fig. 1, I).

Although through further analyses the limits of the different stages will still slightly shift, the present global stratigraphic framework for the marine Quaternary is based on this oxygen isotope stratigraphy. So today the best approach is to correlate the world-wide transgression- and regression-cycles and the sediments belonging to them with these paleotemperature-curves.

AN EXAMPLE FOR MODERN COASTAL GEOMORPHOLOGY

The littoral lowland of Metaponto (Southern Italy) consists of 11 uplifted marine accumulation terraces, T 11 being the highest and T 1 being the lowest Pleistocene one, and of T(O), the Holocene coastal plain. They surround the Gulf of Tarento like a vast amphitheatre and form one of the most imposing series of marine terraces in the whole Mediterranean area. Permanent emergence interfering with glacio-

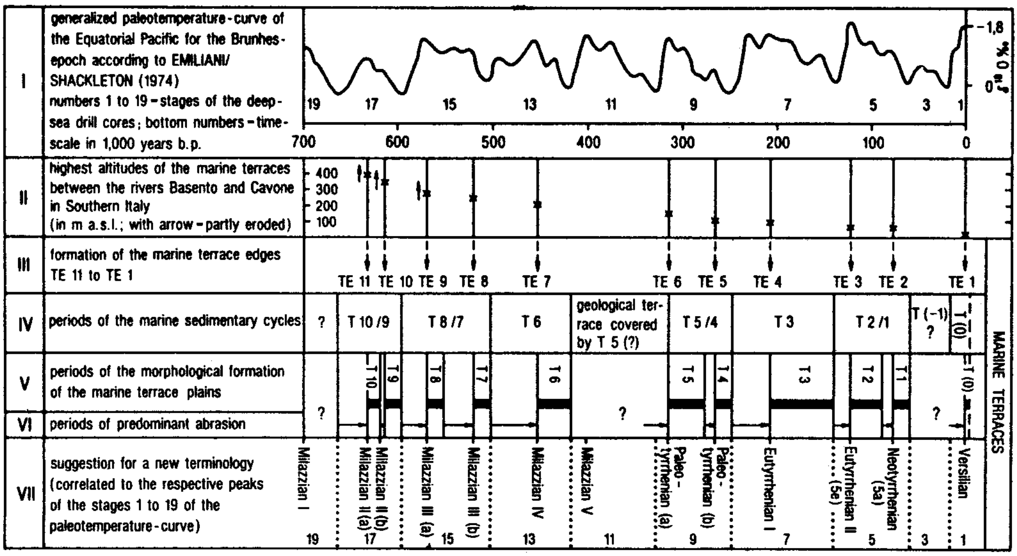

Fig. 1 Synopsis of the correlation between the genesis of the marine terraces in the littoral lowland of Metaponto/Southern Italy and the generalized paleotemperature-curve of the Equatorial Pacific.

eustatic sea-level fluctuations made this sequence of terraces possible.

My studies since 1976 have shown that this region is an excellent example for the correlation between the above mentioned paleotemperature-curves and marine terraces (see Fig. 1).

Fig. 1 is based on the following results:

a) According to paleomagnetic field research the Brunhes/Matuyama-boundary is between T 11 and T 10

b) $^{230}Th/^{234}U$-dated mollusca from T 1 indicate that this lowest Pleistocene terrace was built up in stage 5, more precisely in substage 5a.

c) A dated vulcanic ash layer out of the top-sediments places T 8 in stage 15.

Fig. 1, section I, reproduces the paleotemperature-curve for the Brunhes-epoch with regard to the fact that (a) according to paleomagnetic data the Brunhes/Matuyama-boundary is within stage 19 and (b) the last Pleistocene transgression-maximum was about 125,000 b.p. (see EMILIANI/SHACKLETON 1974, variant D)

The highest altitudes of the marine terraces T 10 to T(O) – normally reached at the foot of the next terrace edge uphill – are shown in section II.

The formation of the terrace edges is correlated with (relatively) high peaks of the curve. The specific correlations result from the above mentioned absolute data and analogy-conclusions based on sediment-petrographical, geochemical and mineralogical analyses (cf. BROCKNER 1980, 151, ff.) (section III).

The formation period of a marine sedimentary cycle starts from the regression-maximum, then continues to the transgression-maximum and ends with the following regression-maximum. Subordinate sea-level fluctuations are not taken into account. These sedimentary cycles create the marine terraces in a geological sense. According to sedimentological analyses, the sedimentary cycles T10/9, T8/7, T6, T5/4, T3 and T2/1 can be differentiated. In addition to these there are sedimentary cycles that created T11 (mainly in the Matuyama-epoch), the only geologically preserved terrace covered by T5 and the submarine T(-1). From the geological point of view the Holocene T(O)-cycle is not yet concluded (section IV).

The formation of a marine terrace in a geomorphological sense (i.e. the formation of the terrace plain) starts after a transgression-maximum which creates the upper terrace edge and lasts till the following regression-maximum (section V).

After the regression-maximum a period of predominant abrasion begins – caused by a following transgression and tectonic uplift –, which partly erodes the earlier sedimented terrace until the next regression stops this process (section VI).

The suggestion for a new terminology (session VII) is based on the correlation with the stages 1–19 of EMILIANI/SHACKLETON's paleotemperature-curve together with absolute data and paleontological evidence. The arguments are in short:

1. The Versilian represents the Holocene transgression-cycle (stage 1).

2. *Strombus bubonius*, the indicator fossil of the Tyrrhenian, lived in the Mediterranean Sea from at least 200,000 b.p. to about 100,000 b.p. (cf. BUTZER 1975, DUMAS 1977) So the world-wide big transgression-cycles around 200,000 and 125,000 b.p. can be called Eutyrrhenian I (stage 7) resp. Eutyrrhenian II (stage 5e).

3. According to this the preceding transgression-cycle is the Paleotyrrhenian one (stage 9, about 300,000 b.p.), the following (a subcycle of stage 5 without *Strombus bubonius*) the Neotyrrhenian one (stage 5a, about 80,000 b.p.).

4. Under the assumption that the terrestrial Cromerian-complex is equivalent to the Milazzian-complex (cf. PFEFFER 1975, OLAUSSON/SVENONIUS 1976, ZAGWIJN/DOPPERT 1978), it covers the period from earlier than 700,000 to about 350,000 b.p., i.e. the stages 19 (or 21?) to 11.

In the littoral lowland of Metaponto these sedimentary cycles interacted with tectonic uplift, thus accumulating the Versilian (stage 1), Neotyrrhenian (5a), Eutyrrhenian II (5e), Eutyrrhenian I (7), Paleotyrrhenian (9) and Milazzian V-I (11-19) terraces.

Another problem under consideration dealt with the construction and the morphogenesis of marine accumulation terraces. Fig. 2 shows the results.

The geological profile normally starts after an erosional disconformity and transgressive facies with fine sediments, becoming coarser towards the top. These strata form the terrace base. Then follow the main gravel layer and finally the top-sedi ments. The respective sedimentary environments are indicated.

The torrential south Italian rivers transport their load to the sea, thus providing the material for the marine terraces. The standardized profile shows that they predominantly owe their genesis to fluvial delta-accumulations into a regressive sea. Fig. 2,

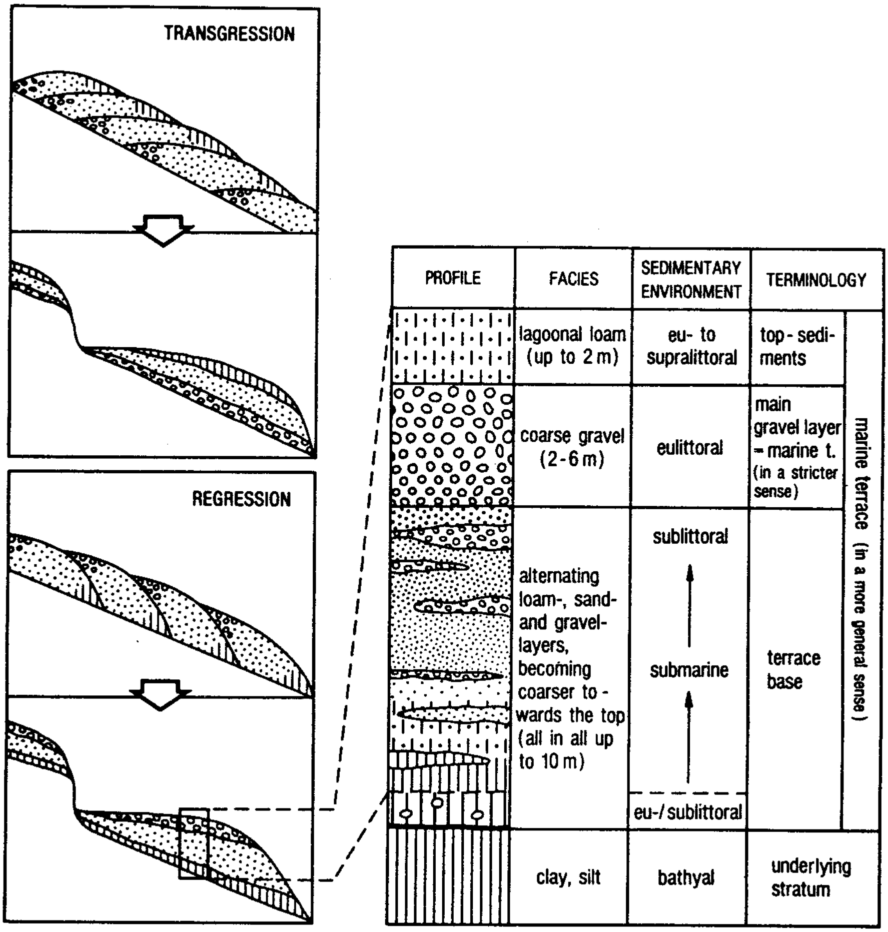

Fig. 2 The marine sedimentary cycle in the standardized geological profile and its predominant genesis by fluvial delta-accumulations into a regressive sea (above left : the totally different profile in the case of a transgressive sea).

left side, demonstrates two principally different stratigraphies of marine accumulation terraces: if fluvial sediments are deposited in a transgressive sea the coarse main gravel layer forms the bottom of the profile, otherwise the top. In some areas even a mixed type may occur with a transgression-conglomerate at the bottom and a coarse gravel layer at the top. Although in the study area only the first type is found, further research must show to which extent the different types occur in other regions.

Fig. 3 gives a general model for the interference of glacio-eustatic sea-level fluctuations and tectonic uplift. This is then applied to a typical profile of an accumulation terrace (the so-called Petrulla-profile in T 1). The sedimentation starts after the first transition of the shoreline, building up the terrace base and the main gravel layer before the second transition of the shoreline takes place. The top-sediments indicate a lagoonal and later a terrestrial environment.

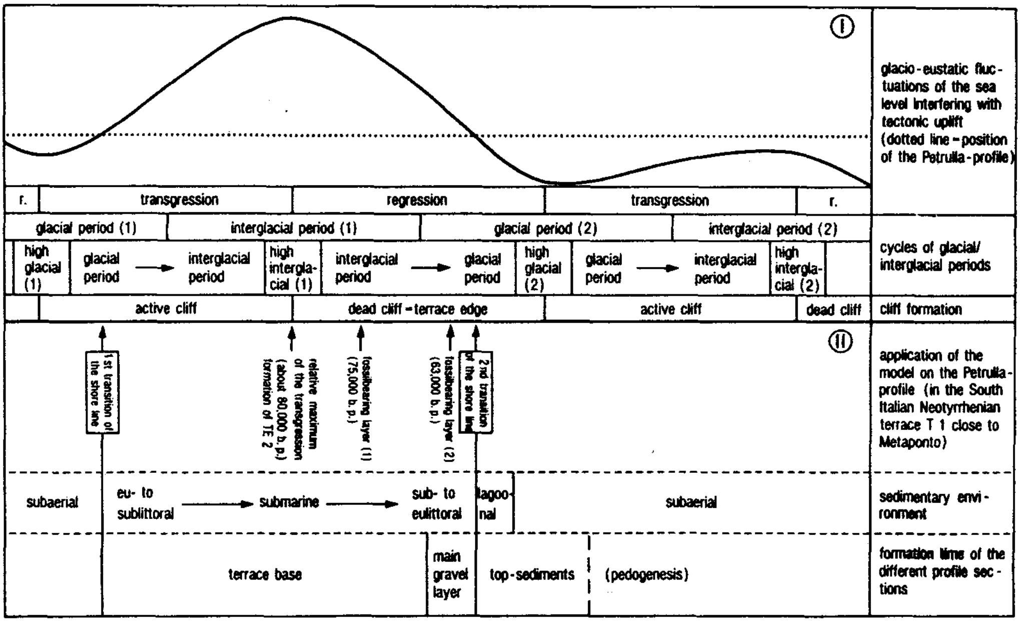

Fig. 3 I. Model for the glacio-eustatic fluctuations of the sea-level interfering with tectonic uplift.

II. Application of the model on a typical profile in the Neotyrrhenian terrace in Southern Italy.

CONCLUSION

The application of chronometric dating techniques and the coordination of the genesis of marine terraces with the paleotemperature-curves of the oceans – as introduced and exemplified in this paper – opens a new field for the modern Quaternary coastal geomorphology.

The suggested terminology is an attempt for a universal definition of the big transgression cycles and the terraces connected with them. The presented models (a) for the genesis of marine accumulation terraces and (b) for glacio-eustatic sea-level changes interfering with tectonic uplift help to under stand the stratigraphy, geomorphodynamics and genesis of some type of raised beaches. Further research shall try to stabilize the terminology and confirm the models in other comparable areas.

REFERENCES

Brockner, H. (1980). Marine Terrassen in Suditalien, Eine Quartarmorpholgische Studie uber das Küstentiefland von Metapont, *Dusseldorfer Geographische Schriften*, **14**, p. 235, Düsseldorf.

Butzer, K. W. (1975). Pleistocene littoral-sedimentary cycles of the Mediterranean basin : a Mallorquin view – in : K. W. Butzer & G. L. Isaac (eds.), *After the australopithecines*, p. 911, Paris, here pp. 25–71.

Butzer, K. W. (1983). Global sea level stratigraphy : An appraisal, *Quaternary Science Reviews*, **2**, pp. 1–15, Oxford/N. Y.

Dumas, B. (1977). Succession et ages radiometriques des terrasses marins du Levant espagnol, *Bulletion de l'Association Francaise pour l'Etude du Quaternaire*, **53 (4)**, pp. 82–85, Paris.

Emiliani, C. (1955). Pleistocene temperatures, *Journal of Geology*, **63**, pp. 538–578, Chicago.

Emiliani, C. & Shackleton, N. J. (1974). The Brunhes Epoch : isotopic paleotemperatures and geochronology, *Science*, **183**, pp. 511–514.

Geyh, M. (1980). *Einfuhrung in die Methoden der physikalischen und chemischen Altersbestimmung*, p. 276, Darmstadt.

Hackens, T. (ed.) (1983). *Third specialist seminar on TL and ESR dating*, Part I, p. 268, Part II, p. 628, PACT, Council of Europe, Strasbourg.

Hennig, G. J. and Gron, R. (1983). ESR dating in Quaternary geology, *Quaternary Science Reviews*, **2**, pp. 157–238, Oxford/N. Y.

Hey, R. W. (1971). Quaternary shorelines of the Mediterranean and Black Seas, *Quaternaria*, **15**, pp. 273–284, Rome.

Hey, R. W. (1978). Horizontal Quaternary shorelines of the Mediterranean, *Quaternary Research*, **10**, pp. 197–203, N.Y./London.

Olausson, E. and Svenonius, B. (1976). Pleistocene changes in the geomagnetic field of the e arth, in : van Zinderen and Bakker (ed.) : *Palaeoecology of Africa and of the surrounding islands and Antarctica*, Vol. **IX**, here, pp. 206–209.

Pfeffer, K. H. (1975). Zur Genese von Oberflachenformen in Gebieten mit flachlagernden Carbonatgesteinen, p. 206, Wiesbaden.

Ruggieri, G. and Sprovieri, R. (1977). A revision of Italian Pleistocene stratigraphy, *Geologica Romana*, **16**, pp. 131–139, Rome.

Shackleton, N. J. and Opdyke, N. D. (1973). Oxygen isotope and palaeomagnetic stratigraphy of Equatorial Pacific core V 28–238, *Quaternary Research*, **3** pp. 39–55, N. Y./London.

Stearns, C. E. and Thurber, D. L. (1965). th^{230}/u^{234} dates of late Pleistocene marine fossils from the Mediterranean and Moroccan littorals, *Quaternaria*, 7, pp. 29–42, Rome.

Zagwijn, W. H. and Doppert, J. W. (1978). Upper Cenozoic of the Southern North Sea basin : Palaeoclimatic and palaeogeographic evolution, *Geologie en Mijnbouw* 57 (4), pp. 577–588, 's-Gravenhage.

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