Bollettino della Società Paleontologica Italiana	24 (1)	1985	3-11	—	Modena, Gennaio 1986

Paleoecological results from foraminiferal assemblage at the top of the Sicilian stratotype-section (Ficarazzi, Palermo, Italy)

Rodolfo SPROVIERI
Istituto di Geologia
Università di Palermo

KEY WORDS — *Foraminifera, Paleoecology, Early Pleistocene (Sicilian).*

ABSTRACT — *On the basis of changes in the generally rich benthic foraminiferal assemblages from a short, closely sampled section representing the topmost part of the Sicilian stratotype section (Puleo quarry, Palermo, Italy) a sharp sea level drop has been detected, evidenced by a biocalcarenitic level interbedded in a predominantly marly sequence. The bathymetric change coincides with a drastic cold climatic event, which correlates with the top of the glacial isotopic Stage 22. The overlaying marly sediments are associated with the base of the interglacial isotopic Stage 21, and reflect a new sea level rise. On the basis of planktonic foraminifera clear climatic fluctuations cannot be recognized, even if generally antithetic, syncronous fluctuations in the abundance of* Globigerinoides ruber *and* Globorotalia inflata *clearly mirror the climatic curve inferred by the more evident Pteropods assemblage variations.*

RIASSUNTO — [Risultati paleoecologici sulla base dei foraminiferi, al top della sezione tipo del Siciliano (Ficarazzi, Palermo, Italia)] — *Lo studio di una campionatura estremamente dettagliata di una piccola sezione ancora affiorante nella località tipo del Siciliano (Càva Puleo, Ficarazzi, Palermo) e rappresentante la parte terminale dello stratotipo di tale sottopiano, ha permesso di mettere in evidenza, sulla base del contenuto in foraminiferi bentonici, un brusco abbassamento del livello marino in coincidenza di un bancone calcarenitico riccamente fossilifero, intercalato in una successione essenzialmente marnosa. Tale abbassamento eustatico coincide con un drastico raffreddamento climatico, pure riconoscibile in tale livello calcarenitico ed essenzialmente evidenziato dalla associazione a Pteropodi, nella quale si riscontra improvvisamente un numero estremamente elevato di esemplari di* Limacina retroversa. *In coincidenza di tale fluttuazione climatica fredda, correlata su basi biostratigrafiche con la parte alta dello Stage isotopico freddo 22, tra i foraminiferi planctonici è riconoscibile una brusca, sensibile diminuzione di* Globigerinoides ruber *e un corrispondente aumento di* Globorotalia inflata, *mentre non si registra nessun sensibile cambiamento nella percentuale di forme destrorse di* Globigerina pachyderma.

FOREWORD

A detailed biostratigraphic framework represents the basic background in the classification of the geologic record. When biostratigraphic events can be placed within an absolute time framework, or confidently related to an absolute dated time scale, they gain even more relevance. In these last years great improvements have been made in the biostratigraphy and biochronology of the Pliocene and Pleistocene. Many calcareous plankton events (foraminifera and nannoplankton) of global value have been recognized in this stratigraphic interval. An integrated biostratigraphy based on entry and exit levels of these two groups of fossils provides for an indipendent check on the reliability and synchroneity of datum levels when the events coincide, and provides for more detailed biostratigraphic and time resolution of the geologic record when they are differently spaced.

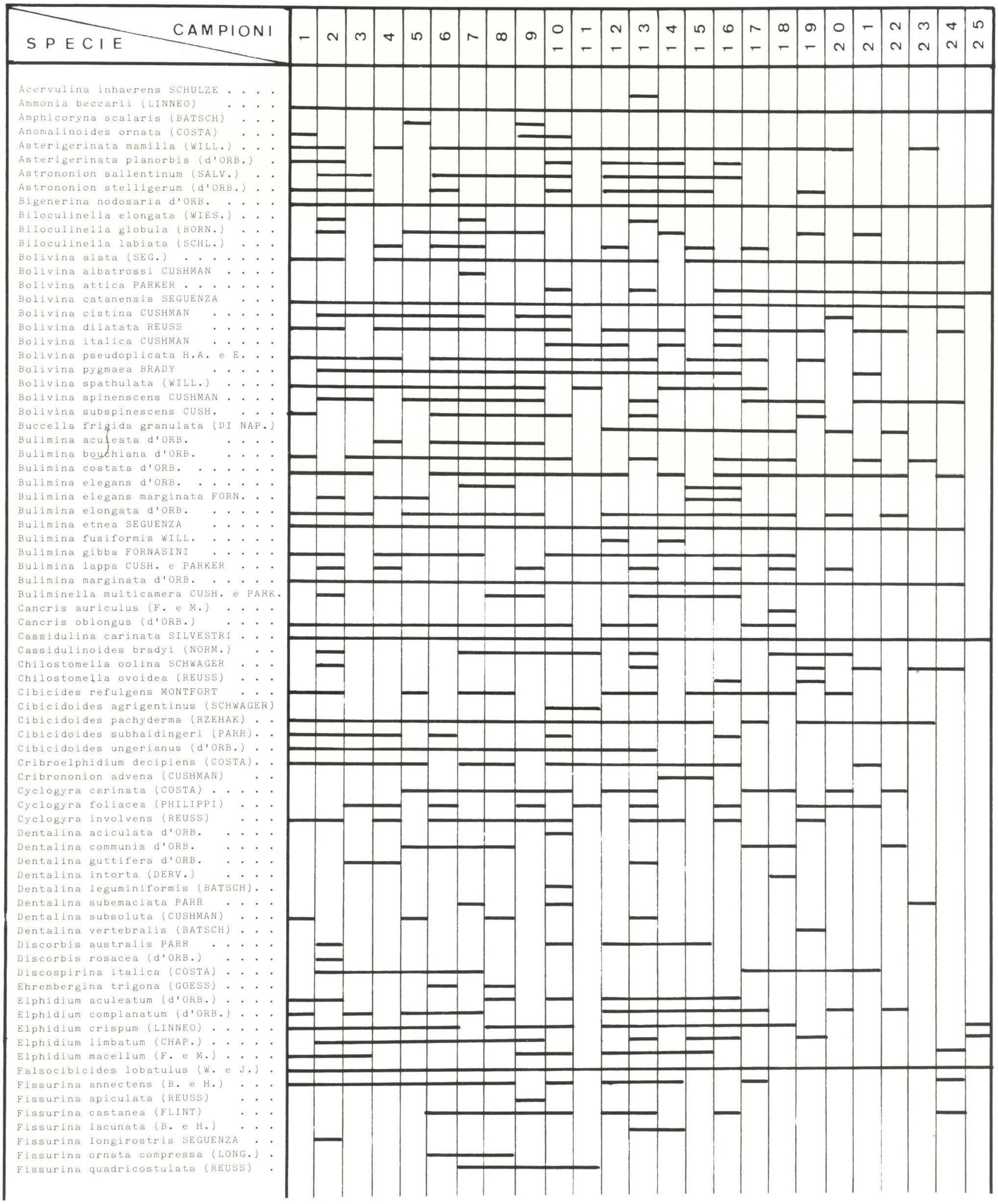
The identification of many of these biostratigraphic events in oceanic sequences (DSDP) in which radiometric and/or paleomagnetic data are available, allow for the calibration of many of these events within an absolute time scheme. They are therefore commonly used for absolute time evaluations (biochronology). Possible diachroneity of these bioevents can be expected within specific climatic-oceanographic regions. During Pliocene and Pleistocene time the Mediterranean acted as a rather distinct biogeographic province (Cita, 1973; Thunnel, 1979) only partially connected with the Atlantic ocean. It is possible, therefore, that first and last occurrences of species recorded in boh the Mediterranean and extra-Mediterranean regions may not always be synchronous. Recalibration of selected oceanic biochronologic events utilizing the recently revised paleomagnetic scale as proposed by Mankinen and Darlymple (1979), their comparison with DSDP results in the Mediterranean (Sites 132 and 125), cross-checking of the estimated ages in other more or less continuous Plio-Pleistocene sections outcropping in Italy by reconstructing the curve of sediment accumulation rate in the most important of them, made it possible (Rio *et al.*, in press; Ruggieri *et al.*, in press) to import and sometimes to recalibrate in the Mediterranean basin some of these extramediterranean bioevents. The fact that these bioevents always occur in the same order suggest that no major diachroneity exists. If we assume that values within a range of about 0.1-0.2 MA can be considered as proof for the synchroneity of an event, depending on operational biases (samples spacing, time of observation, taxonomic difficulties in species identification) and geological or sedimentological shortcomings (subtle changes in sediment accumulation rate, dissolution, mixing due to burrowing, short hiatuses, subtle biogeographic controls on the distribution of fossils in time and space), it can be demonstrated that the estimated ages are well comparable. It is therefore assumed that an error of about 0.1 MA in the lower Matuyama Chron (Latest Pliocene-Early Pleistocene) and of about 0.2 MA during the Gilbert-Gauss (Early-Late Pliocene) interval is not proof of heterochroneity. Such an accuracy in Pliocene time evaluation is superior of that obtainable in most cases by radiochronology.

In recent years an accurate isotopic stratigraphy has identified several major climatic fluctuations in the Neogene and Quaternary. Glaciations are no longer considered peculiarity of the Pleistocene age and the onset of the first ice sheet in the high latitudes of the Northern Hemisphere is referred to an age of about 2.5 MA (Thunell and Williams, 1983), well below the base of the Pleistocene as proposed in the Vrica section (Colalongo *et al.*, 1982). No major coolings exist around the N/Q boundary, although short cool peaks are recognized just around the top of Olduvai (Shackleton and Opdyke, 1976; Thunell and Williams, 1983). Therefore the coincidence of the base of the Pleistocene with the Glacial age must be denied. The inception of a very cold climatic regime in the Quaternary, with the beginning of large temperature fluctuations (base of Glacial Pleistocene according to Shackleton and Opdyke, 1973) is recognized coincident with the isotopic Stage 22. At this time, the first Pleistocene glaciation of typical duration and intensity similar to the Glacial Stages of the Brunhes Epoch as recorded by isotopic stratigraphy is reported. This sharp climatic event occurs just above the top of Jaramillo subchron and before the base of the Brunhes Epoch, at around 0.8 MA (Shackleton and Opdyke, 1976). The base of the *Pseudoemiliania lacunosa* nannofossil biozone coincides (Rio, 1982) with the top of the Jaramillo subchron, at about 0.9 MA. Therefore the beginning of Glacial Pleistocene is in the lower part of this nannofossil biozone.

THE LOWER PLEISTOCENE SEDIMENTARY CYCLE IN FICARAZZI AREA

Two sedimentary cycles can be recognized in Sicily in the Pliocene-Early Pleistocene time-interval. The older one covers, in the most complete sections, all of the Pliocene and lowermost part of the Pleistocene, until the Early Emilian, just above the *Hyalinea baltica* appearance. The younger cycle represents a short transgressive sequence on more or less older sediments. It is Late Emilian and Sicilian in age, with the topmost part generally cut by post-Sicilian erosional surfaces. In the Ficarazzi area only the second transgressive sedimentary cycle is present, as demonstrated by many well exposed outcrops (Ruggieri *et al.*, 1979) and by a continuously cored bore-hole drilled in the Sicilian type-locality (Puleo quarry) which crosses all of the local Early Pleistocene sequence (54 meters thick) down to the basal conglomerate directly overlying the Oligocene-Miocene Numidian Flysch. Micropaleontological data from the bore-hole cores allow easy biostratigraphic correlations. With regards to foraminifera, *Hyalinea baltica* is always recorded; more or less frequent specimens of *Globigerina cariacoensis* are generally present; and *Globorotalia truncatulinoides excelsa* first occurs at 25.7 meters from the top. Therefore, the *Globigerina cariacoensis* biozone is recognizable in the lower part of the sequence, and the *Globorotalia truncatulinoides excelsa* biozone is present in its upper part. The *Globorotalia truncatulinoides excelsa* Mediterranean FAD coincides with the base of the Sicilian chronostratigraphic unit (Ruggieri and Sprovieri, 1977). The nannofossil biostratigraphy is even more detailed (Di Stefano and Rio, 1981; Rio, 1982). The *Helicosphaera sellii* biozone is present in the basal part (till 29 meters from the top), the « small *Gephyrocapsa* » biozone in the middle part (till 12 meters from the top) and the *Pseudoemiliania lacunosa* biozone in the upper part. The continuously cored sequence is followed, after an interpolated unsampled interval of about one meter, by a short thickness of sediments still outcropping in the quarry. This section is studied here in detail and has a total thickness of 6.15 meters. It is represented by two different segments, easily correlatable each other, outcropping at about 200 meters one from the other along the sides of a small channel. It is clearly

Tab. 1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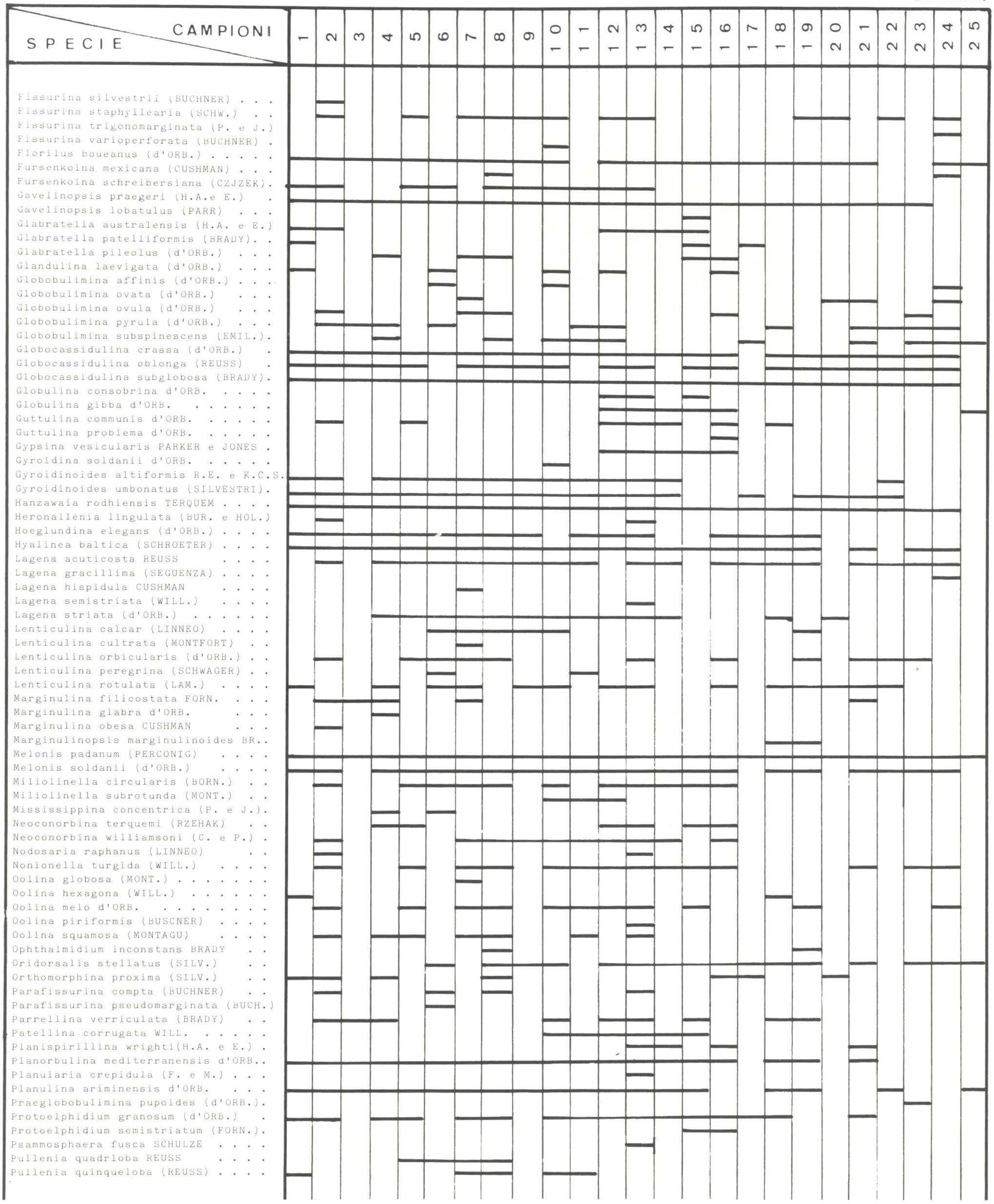
Acervulina inhaerens SCHULZE
Ammonia beccarii (LINNEO)
Amphicoryna scalaris (BATSCH)
Anomalinoides ornata (COSTA)
Asterigerinata mamilla (WILL.)
Asterigerinata planorbis (d'ORB.)
Astrononion sallentinum (SALV.)
Astrononion stelligerum (d'ORB.)
Bigenerina nodosaria d'ORB.
Biloculinella elongata (WIES.)
Biloculinella globula (BORN.)
Biloculinella labiata (SCHL.)
Bolivina alata (SEG.)
Bolivina albatrossi CUSHMAN
Bolivina attica PARKER
Bolivina catanensis SEGUENZA
Bolivina cistina CUSHMAN
Bolivina dilatata REUSS
Bolivina italica CUSHMAN
Bolivina pseudoplicata H.A. e E.
Bolivina pygmaea BRADY
Bolivina spathulata (WILL.)
Bolivina spinenscens CUSHMAN
Bolivina subspinescens CUSH.
Buccella frigida granulata (DI NAP.)
Bulimina aculeata d'ORB.
Bulimina bouchiana d'ORB.
Bulimina costata d'ORB.
Bulimina elegans d'ORB.
Bulimina elegans marginata FORN.
Bulimina elongata d'ORB.
Bulimina etnea SEGUENZA
Bulimina fusiformis WILL.
Bulimina gibba FORNASINI
Bulimina lappa CUSH. e PARKER
Bulimina marginata d'ORB.
Buliminella multicamera CUSH. e PARK.
Cancris auriculus (F. e M.)
Cancris oblongus (d'ORB.)
Cassidulina carinata SILVESTRI
Cassidulinoides bradyi (NORM.)
Chilostomella oolina SCHWAGER
Chilostomella ovoidea (REUSS)
Cibicides refulgens MONTFORT
Cibicidoides agrigentinus (SCHWAGER)
Cibicidoides pachyderma (RZEHAK)
Cibicidoides subhaidingeri (PARR)
Cibicidoides ungerianus (d'ORB.)
Cribroelphidium decipiens (COSTA)
Cribrononion advena (CUSHMAN)
Cyclogyra carinata (COSTA)
Cyclogyra foliacea (PHILIPPI)
Cyclogyra involvens (REUSS)
Dentalina aciculata d'ORB.
Dentalina communis d'ORB.
Dentalina guttifera d'ORB.
Dentalina intorta (DERV.)
Dentalina leguminiformis (BATSCH)
Dentalina subemaciata PARR
Dentalina subsoluta (CUSHMAN)
Dentalina vertebralis (BATSCH)
Discorbis australis PARR
Discorbis rosacea (d'ORB.)
Discospirina italica (COSTA)
Ehrembergina trigona (GOESS)
Elphidium aculeatum (d'ORB.)
Elphidium complanatum (d'ORB.)
Elphidium crispum (LINNEO)
Elphidium limbatum (CHAP.)
Elphidium macellum (F. e M.)
Falsocibicides lobatulus (W. e J.)
Fissurina annectens (B. e H.)
Fissurina apiculata (REUSS)
Fissurina castanea (FLINT)
Fissurina lacunata (B. e H.)
Fissurina longirostris SEGUENZA
Fissurina ornata compressa (LONG.)
Fissurina quadricostulata (REUSS)

Tab. 1 *(continue)*



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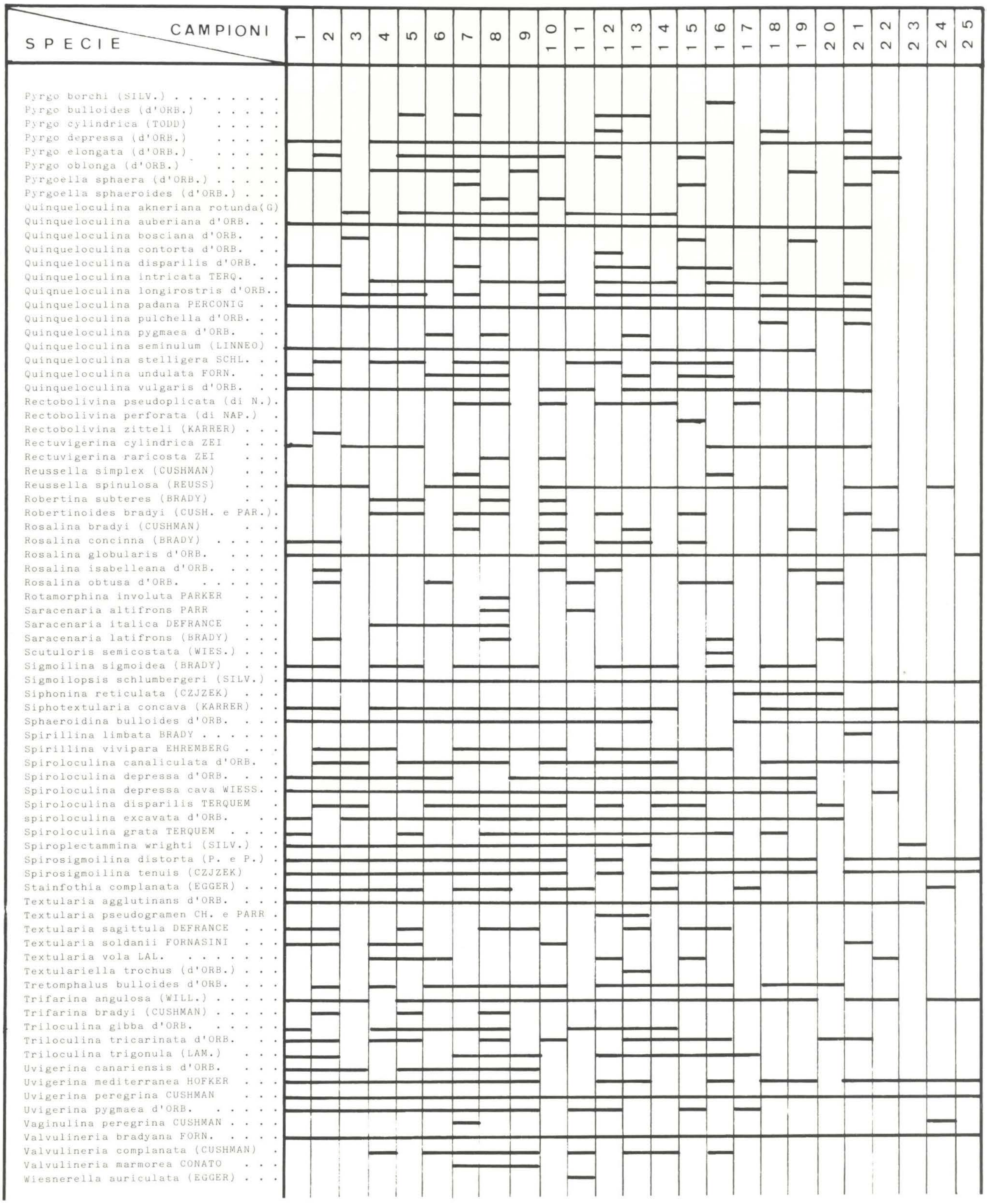
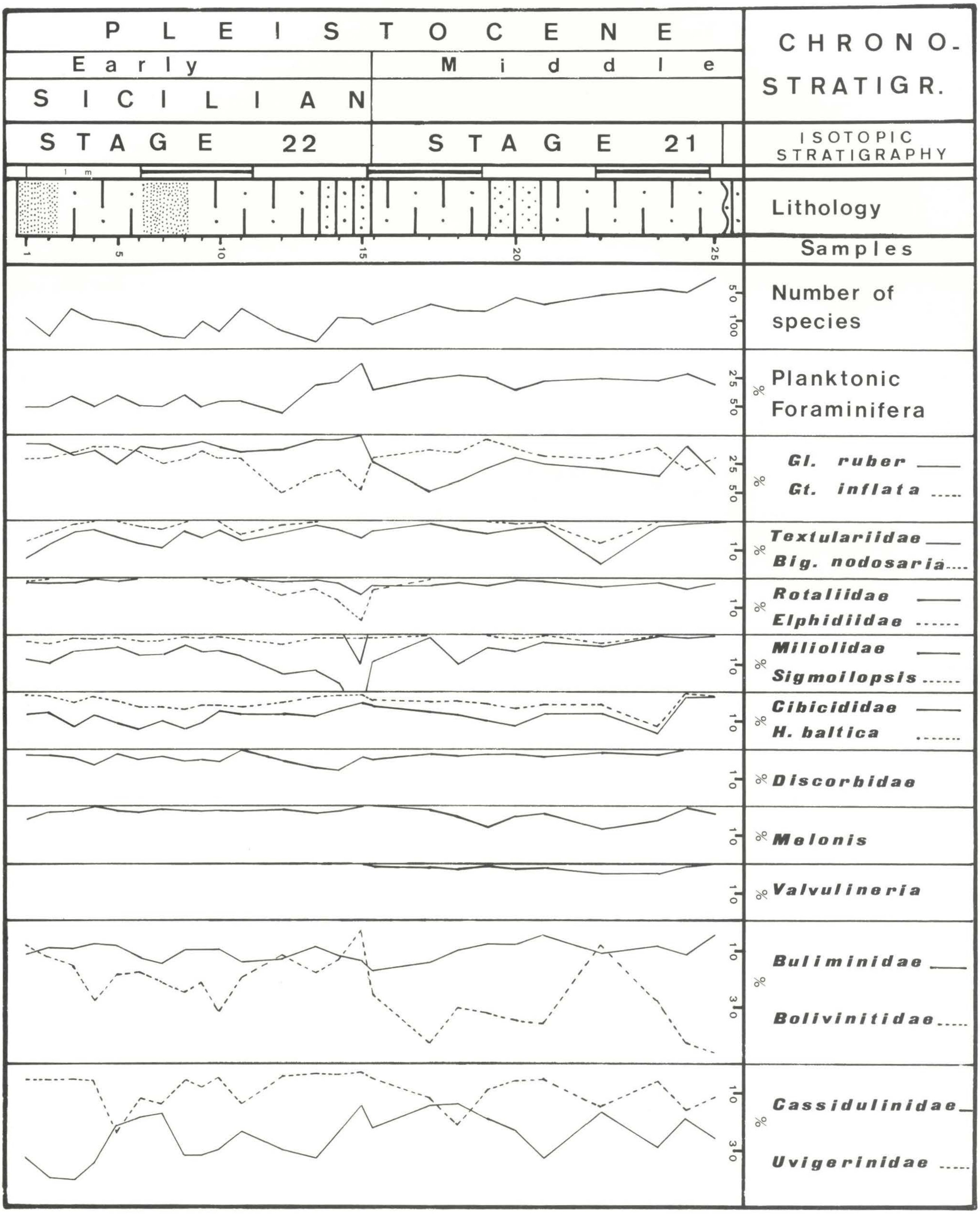


referable to the *Globorotalia truncatulinoides excelsa* foraminiferal biozone and to the lower part of the *Pseudoemiliania lacunosa* nannofossil zone (Di Stefano and Rio, 1981). The small section is dominated by silty marls, with three, several tens of centimeters thick interbedded sandy levels at the bottom, at about 1 meter above the base and about 2 meters below the top, which is transgressively cut by a quarzarenitic post-Sicilian bed. In the middle part of the composite section (2.20 meters above the base), a 40 cm thick biocalcarenitic bed very rich in macrofossils, is present. It represents the classical Sicilian outcrop previously studied by many authors (see Gignoux, 1913). Few macrofossils are present in the marls, but they are common in the sandy levels. The silty marls above the uppermost sandy level are totally devoid of macrofossils. Twenty-five, closely spaced, samples have been collected. Paleoclimatic results coming from a study of the Pteropod assemblages from this section suggest (Buccheri, 1983; 1984) several cold climatic fluctuations, recognized on the basis of the frequence in the samples of the boreal species *Limacina retroversa.* This species is extremely frequent and dominates (about 99%) the Pteropod assemblage coming from the biocalcarenitic bed, where a strong climatic peak can be therefore inferred. Just above, *Limacina retroversa* specimens sharply decrease and are rapidly replaced by several subtropical species. In the topmost part of the sequence Pteropods are totally absent. The cold climatic fluctuations recorded from the outcropping sections and the strong cold event recognized in the biocalcarenitic bed represent the first, and lowermost, strong cooling in the local Early Pleistocene sequence, whose base is older then about 1.2 MA, below the *Helicosphaera sellii* LAD, as discussed above. Since the biostratigraphic position of the biocalcarenitic bed is just a few meters above the base of the *Pseudoemiliania lacunosa* biozone, the coldest peak here recorded is correlated with the coldest uppermost peak of the isotopic Stage 22 (Shackleton and Opdyke, 1976), which is in the same stratigraphic position and represents the oldest strong cold fluctuation in the Pleistocene sequence. Considering this cold climatic event as a natural break in the Pleistocene geologic record, world-wide recognizable in marine and continental environment by biostratigraphic (faunistic and floristic), paleoclimatic, paleomagnetic and isotopic methods, Ruggieri *et al.* (in press) have proposed the top of the biocalcarenitic bed in the section still outcropping in the Puleo quarry as stratotype-boundary of the Early-Middle Pleistocene, and as the upper boundary of the Selinuntian (considered at Stage rank, indicative of the Early Pleistocene) and of the Sicilian (considered as Mediterranean Substage or chronozone, in the sense of Hedberg).

PALEOECOLOGICAL RESULTS

Several Authors (Di Napoli, 1937, 1937a; Emiliani *et al.*, 1958; Gradstein, 1970) studied foraminiferal assemblages from samples collected in the Cava Puleo sediments. Nevertheless, all these studies were always based on samples randomly collected. No detailed sequence of closely spaced samples have been studied. Therefore different results have been obtained. Namely, the drastic climatic deterioration and the sharp bathymetric jump coincident with the biocalcarenitic bed have not been recognized. As a matter of fact, according to Emiliani *et al.* (1958) temperatures as high as 28°C are reported by the isotopic study of the Cava Puleo Sicilian sediments. Accordin to Gradstein (1970) « ... a considerable part of the Sicilian deposits were laid down during a warmer period before a glaciation ». Ottmann and Picard (1954), who took into consideration the rich macrofaunistic assemblage, reconstructed a generalized neritic to epibathyal environment (more than 100 meters in depth) with several shallower displaced species. The frequence of *Arctica islandica* is explained as a consequence of an active deep circulation and not of a real cooling of the waters.

Foraminiferal assemblages have been studied from all the samples in order to obtain paleoecological information. A total of 240 species have been classified, most of which are more or less continuously present in the successive samples (tab. 1). An upward decrease in the number of species per sample has been recognized from the top of the calcarenitic bed. Paleoclimatic fluctuations are not clearly evident from the distribution of planktonic foraminifera. *Globigerina pachyderma* is generally rare and predominantly right coiling. More usefull information was obtained from the relative frequence (over 200 planktonic specimens) of *Globigerinoides ruber* and *Globorotalia inflata.* Repeated, generally antithetic fluctuations of the two taxa abundance (text-fig. 1) are quite well modulated with the cold fluctuations as recorded by the abundance of the Pteropod *Limacina retroversa.* In the coldest, uppermost peak *Globigerinoides ruber,* recognized in the sample in the qualitative approach with specimens characterized by small apertures and tightly coiled spire, does not enter the count in the quantitative approach and its percentage drops to zero; concomitantly, *Globorotalia inflata* is here present with its maximum abundance (50%). In the « warm-temperate » segment above the biocalcarenitic bed, large specimens with big apertures are common in the more frequent *Globigerinoides ruber* population, and *Globorotalia inflata* never exceeds 30%. A similar trend in the *Globigerinoides ruber* frequency has been recognized in Site 132 (DSDP, Leg 13; see Cita *et al.,*



Text-fig. 1 - Character of the total assemblage from each sample, P/B ratio and percentages of the most representative families.

1973) where, coincident with level 4-5, 76 cm, in which the base of the Glacial Pleistocene was detected (in the lower part of the *Pseudoemiliania lacunosa* biozone) *Globigerinoides ruber* is completely lacking.

Paleobathymetric estimates have been inferred from the generally rich benthic population. The character of the total assemblage from each sample, the P/B ratio and the trend of the successive percentages deduced for the most representative families on about 600 benthic specimens per each sample (text-fig. 1) were used to evaluate sedimentation depth and its main fluctuations along the section. In the segment below the biocalcarenitic bed samples yield a generally well diversified benthic assemblage. Bolivinitidae, Buliminidae, Cassidulinidae and Uvigerinidae (*U. mediterranea* is generally well represented) are frequent; Textulariidae (*Bigenerina nodosaria* is sometimes frequent and decreases in the upper samples), Cibicididae, (*Hyalinea baltica,* sometimes frequent, decreases in the upper samples; *Gyroidinoides altiformis* is constantly present, but rare) and Discorbidae (which slowly increase upwards) are generally common, with no major fluctuations. Miliolidae are always present and gradually increase in top samples, as Elphidiidae and Rotaliidae, which are rare or absent at all in the lowermost part: many specimens are broken or corroded, probably displaced. Nodosariidae are very rare, essentially represented by *Dentalina* (*D. guttifera* and *D. subsoluta* are occasionally present with rare specimens), *Lenticulina, Saracenaria* and rare *Amphicoryna scalaris. Discospirina italica* and *Hoeglundina elegans* are always present and sometimes common. Planktonic foraminifera are well represented, with a mean percentage of about 50%.

Samples coming from the biocalcarenitic bed, and from its topmost part in particular, contain a different assemblage. It is very rich but less diverse. The percentages of Bolivinitidae, Cassidulinidae and Uvigerinidae drop to their minimum values, and Cibicididae and Discorbidae are rare. On the contrary, Elphidiidae and Rotaliidae, with large and well preserved specimens, abruptly increase. In addition, Textulariidae are frequent but *Bigenerina nodosaria* is absent. Miliolidae, with prevailing well preserved, large specimens of ribbed *Quinqueloculina*, are now extremely frequent (up to 30% of the total benthic population). Nodosariidae are totally absent; *Hoeglundina elegans, Gyroidinoides altiformis* and *Discospirina italica* disappear; *Hyalinea baltica* is present, but it is very rare. P/B ratio greately decreases, with the planktonic forms at about 15%. Absence of grading or lamination, the generally excellent preservation of specimens (even in Miliolidae, whose test is easely corroded during displacement) (but some displaced specimens are also present) and the rich well preserved Pteropod assemblage, whose thin tests can be hardly displaced without demage, would exclude the possibility of considering the biocalcarenitic bed as turbidites or transported mass flow deposits.

In the uppermost segment, above the biocalcarenitic bed, the benthic assemblage changes again. The number of species per sample gradually decreases until only 23 species are present in the topmost sample. Cassidulinidae, Bolivinitidae and Uvigerinidae increase and are generally frequent. Cibicididae are now better represented, while Discorbidae decrease; *Melonis*, very rare in the underlying samples, attains its maximum relative frequency and *Valvulineria* for the first time enter the count. Miliolidae, Textulariidae (*Bigenerina nodosaria* is very rare), Elphidiidae and Rotaliidae sharply decrease. Nodosariidae with rare *Lenticulina* and *Dentalina*, are presena again; *Discospririna italica, Hyalinea baltica* and *Hoeglundina elegans* reapper. The P/B ratio increases, and plankton are about 30%.

According to the above discussed characters and by comparison with bathymetric distributions of recent Mediterranean foraminifera (Parker, 1958; Blanc-Vernet, 1969; Wright, 1978), the basal segment is referred to the uppermost part of the epibathyal zone with an inferred water-depth of about 200 meters, gradually and slowly decreasing upwards. The biocalcarenitic bed is referred to the middle part of the outer neritic zone, with an estimated paleodepth of about 70-100 meters. The uppermost segment is referred, after a short transitional interval at the base, to the lower part of the outer neritic zone, with an inferred paleodepth of about 120-150 meters.

CONCLUSIONS

On the basis of the faunal changes within the benthic foraminifera, a well detectable sea level drop of about 100 meters has been recognized at the top of the Sicilian stratotype section, testified by the biocalcarenitic bed in which the first local cold peak of the early Pleistocene sequence was detected. This climatic event is correlated by biostratigraphic and paleoclimatic methods with the top of isotopic Stage 22. Bathymetric estimates in the overlying sediments, characterized by a « warm-temperate » assemblage and correlated with the base of the isotopic Stage 21, indicates a sea level rise. These bathymetric fluctuations are parallel to the isotopic fluctuations of Stages 22 and 21. Namely, the strong $\delta\ ^{18}O$ increase at the top of Stage 22, correlatable with an abrupt sea water storage on the continents during expansion of the polar ice sheet, coincides with a maximum, quite abrupt sea level drop. A sharp decrease in $\delta\ ^{18}O$ coincides with the base of Stage 21, presumably related to water imput in the oceans as a consequence of ice melting.

Therefore, a sea level rise must be expected. Accordingly, a rapid and significant sea level rise is recorded in the part of the section referable to the base of Stage 21. The results discussed here show that the paleodepth of the thin sediments referred to the lowermost part of the isotopic Stage 21 is shallower than the one recorded from the basal part of the section predating the strong, cold climatic event.

AKNOWLEDGMENTS

Many thanks are due to R. C. Thunell who improved the English manuscript. Support for this work was provided by Ministero della Pubblica Istruzione.

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(manuscript received January 12, 1984
accepted June 29, 1984)

Rodolfo SPROVIERI
Istituto di Geologia
Corso Tukory, 131 - 90134 Palermo, Italia