

Oxygen isotopic composition of some Pelecypoda from two Calabrian faunas

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RIASSUNTO — È stato misurato il contenuto in O^{18} del carbonato di calcio di conchiglie di lamellibranchi fossili provenienti dai giacimenti calabriani di Vallebiaia e Luciana. Per le caratteristiche della fauna, il primo dei due giacimenti è ritenuto posteriore al secondo.

Le specie prese in esame sono trentatre, nove delle quali in comune alle due faune. I risultati ottenuti non possono essere interpretati in termini esatti di temperatura, non essendo nota la composizione isotopica del mare nei due diversi momenti del Calabriano. Ad ogni modo, per sette delle specie comuni, gli esemplari raccolti a Luciana hanno mostrato un contenuto in O^{18} maggiore di circa un'unità di δ rispetto agli esemplari raccolti a Vallebiaia. Due specie, *Arcopagia ventricosa* e *Venus fasciata*, mostrano invece un comportamento anomalo. Dal contenuto in O^{18} degli esemplari di *Arcopagia ventricosa* si può dedurre che, mentre a Luciana (anaglaciale) gli individui appartenenti a questa specie formavano la loro conchiglia nel periodo estivo, a Vallebiaia, quando già il clima si stava evolvendo verso un interglaciale, gli individui della stessa specie preferivano la stagione invernale per deporre il carbonato di calcio.

In base a ciò e a diverse considerazioni relative da un lato al comportamento delle specie plioceniche estinte entro il culmine della prima glaciazione e dall'altro al comportamento di quelle che, essendo riuscite a superare il culmine della prima glaciazione, andarono poi estinguendosi nel corso dei successivi interglaciali, è possibile dedurre quanto segue.

Quando una specie, già adattata ad un certo ambiente, deve affrontare una variazione climatica, può tendere a conservare l'intervallo di temperatura di deposizione del carbonato di calcio a lei più opportuno, indipendentemente dall'avvicendamento stagionale, oppure può rimaner legata al periodo stagionale nel quale già prima era solita deporre il carbonato di calcio, adattandosi ad un nuovo intervallo di temperatura per la deposizione stessa. Talvolta è possibile un compromesso fra queste due diverse tendenze; tuttavia, quando le variazioni tendono a divenire troppo ampie, una delle due esigenze finisce col prevalere, provocando la differenziazione di un nuovo ecotipo che può anche presentare caratteri morfologici particolari, riconoscibili nella conchiglia. Il nuovo tipo specializzato può essere inadatto a sopravvivere ad ulteriori variazioni climatiche in senso opposto.

Le ipotesi enunciate potranno essere confermate da successive ricerche: comunque, si delinea già dal presente studio la possibilità che l'indagine sulle paleotemperature possa portare un fondamentale contributo alla definizione di quelle entità sistematiche che possono talvolta risultare di difficile interpretazione.

The isotopic composition of oxygen (O^{18}/O^{16}) in calcium carbonate can be used to calculate the temperature at which the carbonate was deposited [cf. the fundamental papers of H.C. Urey (1947), J.M. McCrea (1950), H.C. Urey et al. (1951), S. Epstein et al. (1951, 1953)]. This is possible when

the isotopic composition of the water, in which deposition took place, is known. Apart from some special cases the isotopic composition of sea water can be considered to be fairly accurately known. Consequently many marine calcitic fossils can be used for paleotemperature analyses.

Two different kinds of informations can be obtained from measurements on Quaternary Molluscs:

a) the value of the climatic variations determined by the glacial and interglacial periods and the climatic situation of different single layers in a marine Quaternary sedimentary cycle (this is chiefly useful when recent tectonic movements prevent the study being made by considering the Quaternary eustatic movements as a basis);

b) valuable biologic and palaeontological informations on the behaviour of different species during the transition from a relatively cold (glacial) to a relatively warm (interglacial) period, and vice-versa.

In both cases a comparison between similar faunas occurring in different layers is required. Two difficulties prevent such a comparison:

1) the isotopic composition of the sea water, and particularly of the Quaternary Mediterranean sea, changed in time; in fact such a variation is particularly influenced by evaporation and precipitation and the contribution of fresh waters from melting ice. Other important factors are the variability of the sea currents and of the salinity and, consequently, the different exchange through the Gibraltar strait between Mediterranean and Atlantic waters. These factors cannot be exactly stated and a precise value of the variations in the O^{18} content cannot be theoretically estimated;

2) climatic variations must exert selective pressure and consequently cause ecologic differentiations. Such a condition could determine variations in biological behaviour, chiefly in species which deposited their calcium carbonate only during one part of the year, and hence were more susceptible to selection pressure exerted by climatic change.

Concerning the first item, the difficulty can be eliminated according to the work of A. P. Tudge (1960). In fact the isotopic composition of the sea water can be established by measuring contemporaneously

the calcium carbonate and phosphate. By this method all the variations of the isotopic composition of oxygen in sea water through geological time can be revealed.

Concerning the second item, we have to investigate either on single species surviving during time or, comparatively, on faunas from different layers but containing species in common. In the second case (which is just the subject of our investigation), if the amount of the species is high enough, we should obtain single values of the oxygen isotopic composition scattered over a rather large range, whose extremities are supposed to represent the averages of summer and winter temperatures. Thus we can check whether each species from different faunas has deposited its calcium carbonate always in the same season of the year or has changed the time interval in which deposition took place. From this point of view it is not necessary to know the isotopic composition of the sea water and the real value of the temperature at which the calcium carbonate deposition took place.

Fossils from Calabrian sediments are of particular interest because the behaviour of many species surviving into the Quaternary from Miocene and Pliocene periods can be followed. From the palaeontologic point of view the Calabrian faunas can be divided into four groups:

- I) faunas similar to those of the Pliocene, but with some species which had lived, during the Pliocene, in deeper waters (vertical migration),
- II) faunas with deep-water species, cold Atlantic immigrated species, and some Pliocene species still surviving but after this moment disappearing,
- III) faunas very similar to the precedings, but without the Pliocene survivals of II,
- IV) faunas of little significance, in which deep-water species and cold Atlantic immigrated species are very scarce and finally disappear.

MEASUREMENTS AND RESULTS

Our measurements have been carried out on a group of 31 species of Pelecypoda from a Calabrian clay-sandy layer, some decimeters thick, at Vallebiaia near Fauglia (Livorno), 43°34'05" N and 10°29'09" E, and on a group of 11 species from another Calabrian layer of the same sedimentary complex near the village of Luciana (Livorno), 43°32'55" N, 10°29'46" E.

The Vallebiaia fauna, formerly studied from the systematic point of view by Socin (1941) and Giannini (1948) must be considered as an intermediate one between III and IV above. On the contrary, in the Luciana layer (faunistically poorer than the Vallebiaia one) some shortly surviving Pliocene species do occur together with cold Atlantic immigrated species, these more abundant than in the Vallebiaia fauna. Thus the Luciana fauna must be palaeontologically classed in the II group as above.

The samples have been prepared by using the method proposed by S. Epstein et al. (1953). Three powdered samples from each specimen were roasted for one hour and a half at least, at 470° C under a purified helium flow of more than 25-30 cc.p.m. Only platinum boats have been used. The CaCO_3 was later on reacted with 100% phosphoric acid at 25.2° C. The isotopic composition of CO_2 was measured by means of an Atlas M86 dual collector mass spectrometer.

The results, shown in Table I, are expressed in terms of difference per mil (δ) of the ratio $0^{18}/0^{16}$ between the sample and the PDB 1 standard. The working standard was a very pure Carrara white marble, whose 0^{18} content is -1.60‰ if compared with PDB 1 standard.

Consistent results have been normally obtained with a mean reproducibility better than 0.1 δ . The results listed in Table I represent for each specimen the average value between the three measured samples. For some species two specimens have been measured.

TABLE I

δ 0^{18} content (PDB1) of the measured specimens

	Luciana	Vallebiaia
1 <i>Nucula nucleus</i> (L.) .	—	+ 1.37
2 <i>Leda pella</i> (L.) . . .	—	+ 0.36
3 <i>Arca syracusensis</i> Mayer	—	+ 1.14
4 <i>Arca tetragona</i> Poli . .	—	+ 0.79
5 <i>Glycymeris glycymeris</i> (L.)	+ 1.54	+ 0.22
6 <i>Glycymeris insubricus</i> Brocchi	—	+ 0.12
7 <i>Pecten planariae</i> Simonelli	—	+ 0.71
8 <i>Amussium cristatum</i> Bronn	+ 1.51	—
9 <i>Chlamys varia</i> (L.) . .	+ 1.35	+ 0.37
10 <i>Chlamys inaequicostalis</i> Lmk	—	+ 1.48
11 <i>Plicatula mytilina</i> Phil.	—	+ 0.05
12 <i>Astarte fusca</i> Poli . .	+ 3.08	+ 2.06
13 <i>Cardita elongata</i> Bronn	—	+ 0.02
14 <i>Cyprina islandica</i> L. .	+ 2.77	+ 1.83
15 <i>Lucina borealis</i> L. .	+ 2.13	+ 1.09
16 <i>Chama placentina</i> De-france	—	+ 0.28
17 <i>Cardium echinatum</i> (L.)	—	+ 0.06
18 <i>Cardium multicostatum</i> Brocchi	—	+ 0.07
19 <i>Cardium hians</i> Brocchi	—	+ 0.64
20 <i>Cardium edule</i> (L.) . .	+ 1.80	+ 0.06
21 <i>Cardium oblongum</i> Chemnitz	—	+ 0.21
22 <i>Dosinia exoleta</i> (L.) . .	—	+ 0.48
23 <i>Venus lamellosa</i> Rayneval	—	+ 0.41
24 <i>Venus verrucosa</i> (L.) .	—	— 0.32
25 <i>Venus ovata</i> Pennant .	+ 0.13	—
26 <i>Venus fasciata</i> Da Costa	— 0.83	— 0.12
27 <i>Tapes rhomboides</i> Pennant	—	+ 0.21
28 <i>Macra subtruncata</i> Da Costa	—	+ 1.25
29 <i>Tellina donacina</i> (L.) .	—	+ 0.75
30 <i>Tellina serrata</i> Renier	—	+ 0.53
31 <i>Arcopagia ventricosa</i> De Serres *	— 0.14	+ 2.06
32 <i>Panopaea glycymeris</i> Born var. <i>faujasi</i> Men.	—	+ 1.93
33 <i>Corbula gibba</i> Olivi .	+ 2.14	+ 1.21

* The specimens from Luciana are smaller than those from Vallebiaia. Two specimens from a fossiliferous layer near Lari, with the same geological and paleontological meaning of Luciana, have been measured. The δ 0^{18} values are -0.24 and -0.28 and the shape and the dimensions of the shells are just the same as those of the specimens from Vallebiaia.

The range of the isotopic composition observed in the Vallebchiaia Pelecypoda corresponds to an interval of about 10°C in sea water temperature. The minimum and maximum δ values obtained represent for each measured specimen mean values of the whole period of calcium carbonate deposition. The corresponding temperature range looks rather reasonable as at present in the Mediterranean sea at the latitude of Vallebchiaia the annual temperature range is about 12°C at the surface. Consequently, such a temperature record supports the assumption that the depth of the Vallebchiaia sea was rather low at that moment.

The results obtained for the different species can be classed into:

a group including the species which deposited their calcium carbonate during summer,
a group including the species which deposited their calcium carbonate during intermediate seasons or throughout the whole year,
a group including the species which deposited their calcium carbonate during winter.

The amount of species per 0.25 δ unit classes is reported in fig. 1. The modal value, if compared with the mean value, is clearly displaced towards the inferior limit, i.e.

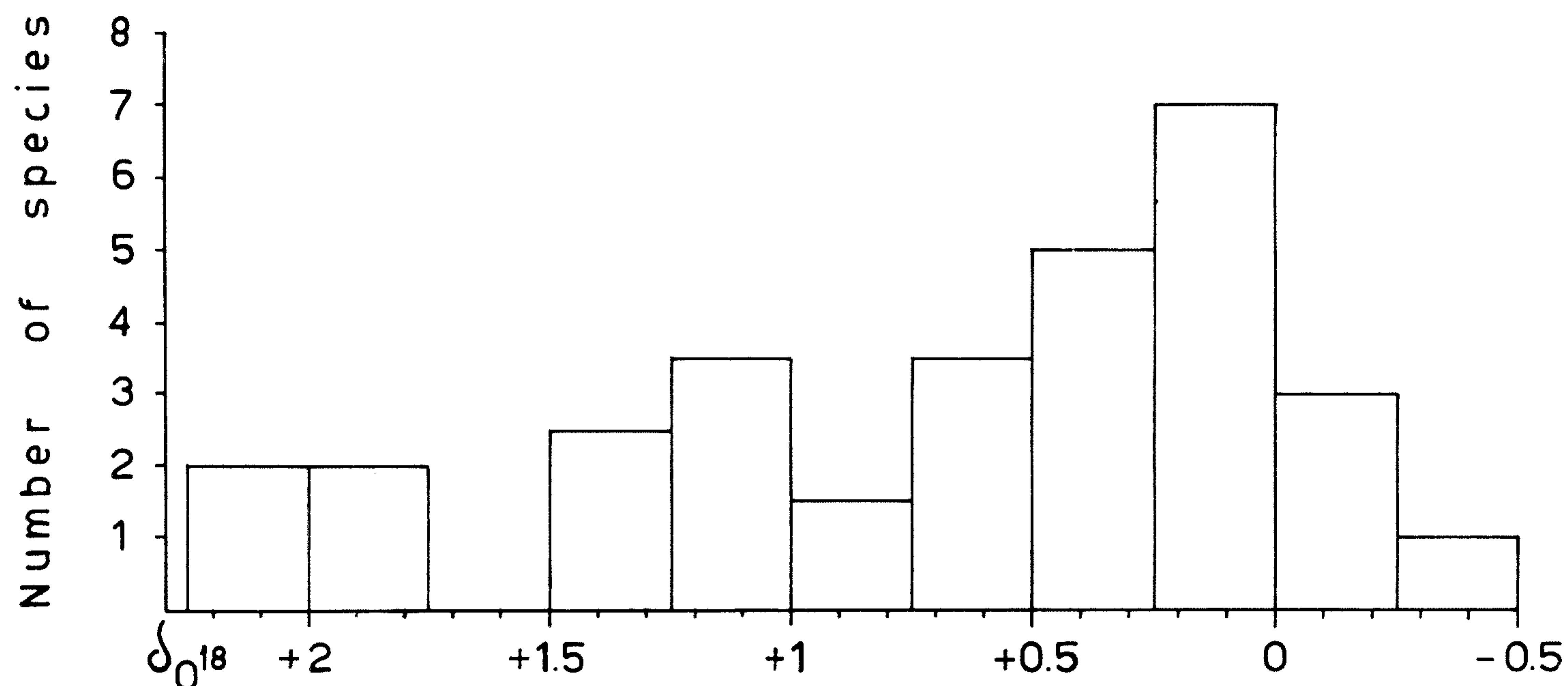


Fig. 1

Number of species per 0.25 δ unit classes.

towards warm temperatures. One can explain this fact by assuming the tendency of many species, already adapted to a warm sea, to maintain their temperature interval of calcium carbonate deposition, even after a climatic variation towards a colder period.

In the case of the fauna from Luciana, the temperature range corresponding to the isotopic composition range is about 15°C . This range is larger than the Vallebchiaia one. Remembering that the fauna from Luciana is rather poor concerning the amount of both species and specimens, we can conclude that the depth of the Luciana sea was

even more little than that of the Vallebchiaia sea.

The O^{18} content of seven species, common to both faunas, is, in the case of Luciana, higher by about one δ unit than that of Vallebchiaia. The constancy of such a difference can be explained either in terms of temperature variation or in terms of different isotopic composition of the sea water. It is rather unlikely that in two different moments of a glacial period one of which very probably preceded and the other one followed the maximum of the glaciation, the isotopic composition of the sea water or its

mean temperature value remained exactly the same.

Probably both temperature and sea water isotopic composition did influence the recorded values.

In any case two species show an anomalous behaviour if compared with the seven

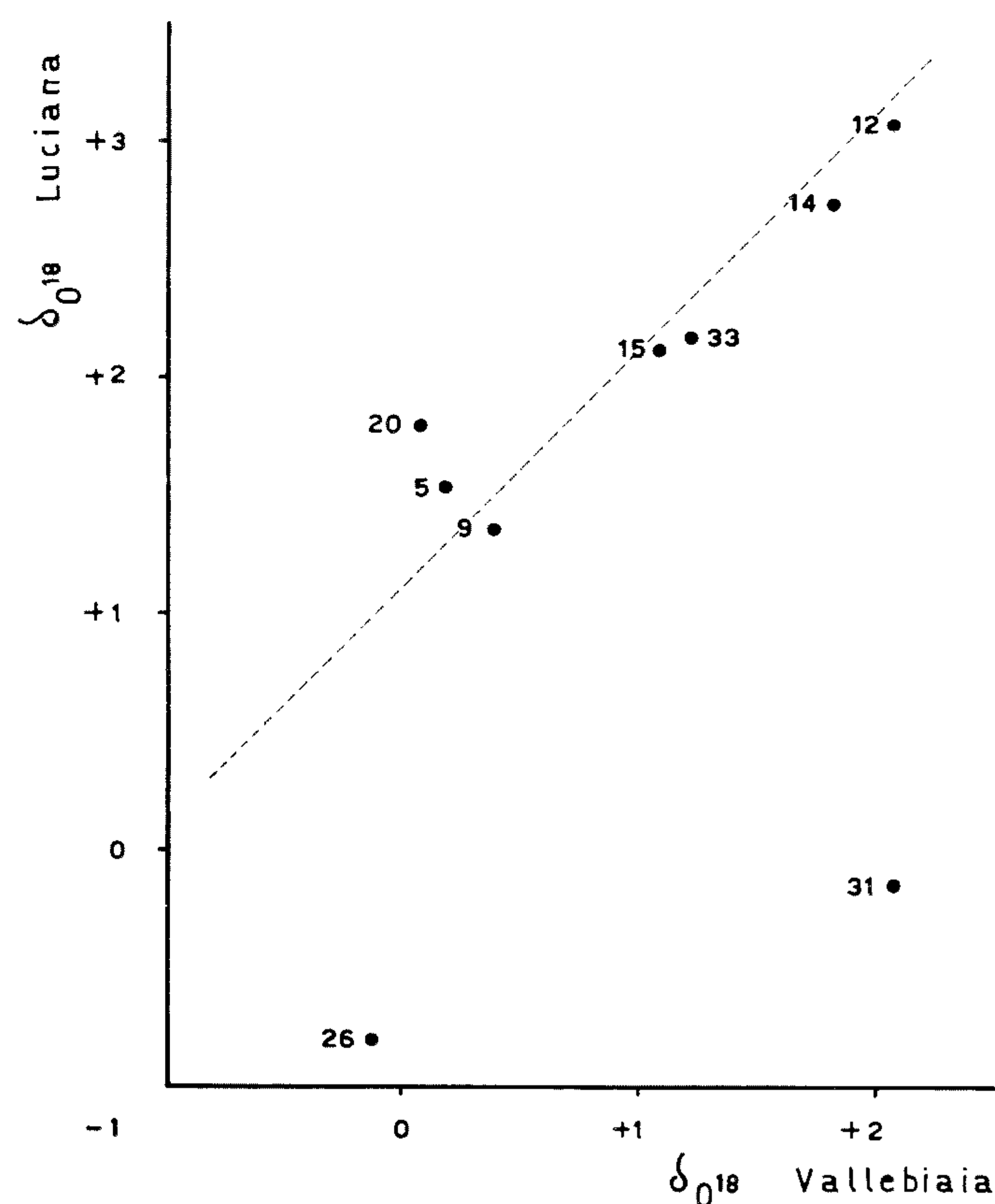


Fig. 2

$\delta^{18}O$ values for species (same numbers as Table 1) found at Vallebiaia and Luciana. The dotted line represents a constant difference of 1.1 $\delta^{18}O$.

species above. In fact the representative points of *Arcopagia ventricosa* and *Venus fasciata* in fig. 2 are away from the straight line which can be traced through the representative points of the other species.

If the behaviour of *Arcopagia ventricosa* paralleled that of the other species represented in both faunas, a δ value of -0.14 in the specimens from Luciana should have to correspond to a δ value < -1 in the specimens from Vallebiaia. Such a value of the calcium carbonate isotopic composition is lower than the minimum values registered by the measured Pelecypoda from Vallebiaia

and probably it was impossible to be reached.

The genus *Arcopagia* is now nearly extinguished in the Mediterranean sea. We can find species similar to those of the Pliocene Mediterranean faunas only off the western coast of Africa. We may surmise that at Luciana, during the anaglacial phase and under littoral conditions, the survival of specimens which preferred warm conditions was still possible. On the contrary, the maximum glacial phase prevented this survival as it was for other Tertiary species. In the case of *Arcopagia ventricosa* the extinction was not complete. At Vallebiaia, specimens of this species deposited their calcium carbonate during winter. Clearly, during the glacial period, selection pressure determined an echotype of this species which required different conditions than the summer echotype whose specimens have been measured at Luciana and Lari.

The behaviour of the other species '*Venus fasciata*' is not far from that of *Arcopagia ventricosa*. Also in this case the species is to-day practically extinguished in the Mediterranean sea, where is living the « var ». *brongniarti* Payr, whose shape is rather similar to that of fossil specimens of *V. fasciata*. Very likely the type of Luciana, particularly suited to a rather warm habitat, was not able to survive the maximum of the glacial period and generated an other type, still preferring rather high temperatures, but suited to the new climatic situation.

The above considerations suggest that when species must face climatic changes of some rigour, they try to maintain

a) the temperature interval which, up to that period, represented their biological optimum for calcium carbonate deposition: in this case they must form calcium carbonate at a different season,

b) the time interval in which they precipitate their calcium carbonate: in this case they must adapt to different temperature conditions.

Probably, in some cases a variation in both directions can occur, but, when a rather large variation of the time interval is necessary to maintain the temperature interval and vice-versa, only the differentiation of a new echotype enables the species to survive. This new echotype can also have peculiar morphologic characters which permit its determination as a distinct taxonomic unit.

The new specialized echotype can be unable to survive other climatic variations. In such a way we can explain the extinction of some species which, having survived the maximum of a glacial period, have not been able to survive the next interglacial.

Study of other glacial and interglacial faunas is needed to confirm the hypothesis above. In any case the importance of palaeotemperature measurements must be emphasized as a remarkable aid in the determination of echotypes and subspecies and of all those taxonomic units which sometimes are difficult or almost impossible to interpret.

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