10. J. A. Hunt, *Nature* **183**, 1373 (1959).
11. A. M. Katz and D. L. Rucknagel, unpublished observations.
12. We wish to thank Christian B. Anfinsen and W. J. Dreyer for their encouragement and advice. This study was supported in part by grant No. A2956 from the National Institutes of Health, U.S. Public Health Service.
* Present address: Massachusetts General Hospital, Boston.

13 July 1959

Oxygen Isotope Paleotemperature Determinations of Australian Cainozoic Fossils

Abstract. Fossil marine shells collected in southern Victoria within half a degree of latitude of 38½ °S have been analyzed for O^{18}/O^{16} by mass spectroscopy, and their paleotemperatures have been determined. For the genera *Chlamys, Ostrea,* and *Glycymeris* the temperature rises from early to mid-Tertiary, then falls again to the present.

The method of Urey and his co-workers (*1*) was used to determine paleotemperatures, the experimental accuracy being estimated as about 1°C, made up of instrumental errors and variation in the CO_2 preparations using phosphoric acid. Errors due to alteration of the fossil carbonate cannot be estimated, but a careful selection of shells together with a thorough mechanical cleaning of their surfaces was made to minimize variations. The absolute value of the temperature scale was determined to be within 1°C of the Chicago standard PDB II, but living shells gave values about 2°C lower than averaged sea-water temperatures. Epstein and Lowenstam (*2*) also found a variation between sea-water and shell O^{18}/O^{16} temperatures in Bermuda shoal waters, where pelecypods and gastropods had different growth habits, resulting in different isotope temperatures in the same waters. An *Anadara* shell from Moreton Bay, Queensland, was found by us to have a value 5°C below the sea-water temperature, but this was probably due to its living between tide marks. This mollusk thus lived part of the time at a mud-water interface and part of the time at a mud-air interface.

Mollusks from Melbourne and a limpet from Macquarie Island yielded isotope temperatures about 2°C lower than measured sea-water temperatures. This difference is interpreted as being due to the growth habits of the organisms, to the difference between the mean temperature of the sites where they lived and the sites where the temperatures were measured, or to both. Despite these drawbacks inherent in using specimens from shelf faunas [see also Epstein *et al.* (*1*) and Lowenstam and Epstein (*3*)], a definite picture of the paleotemperature changes can be seen.

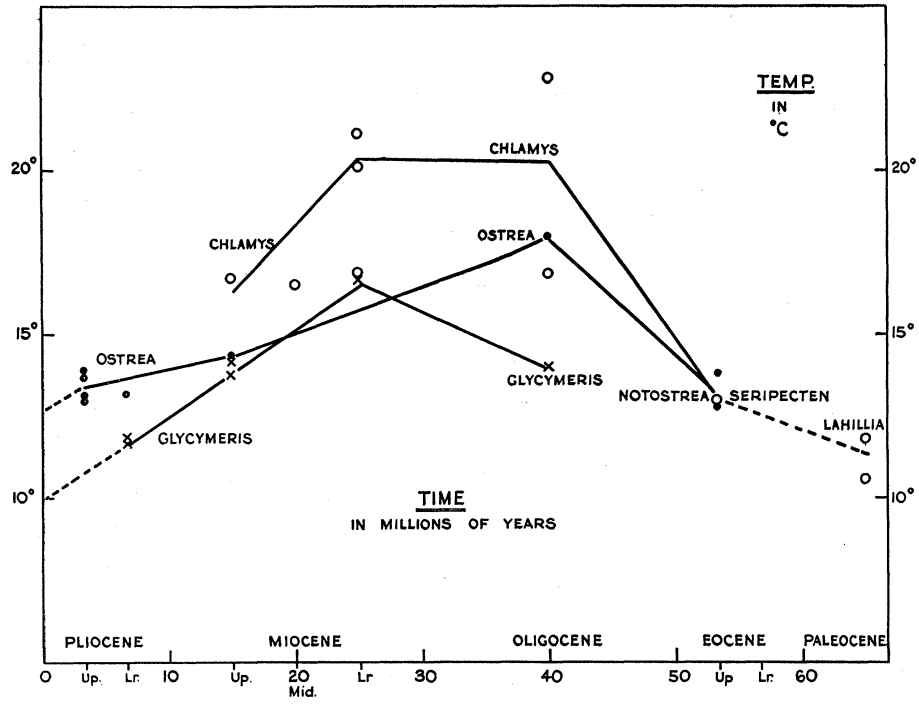

Fig. 1. Results obtained for the Tertiary fossils. The sites which yielded the fossils whose paleotemperatures are given are as follows:

Age	Species	Site
Pliocene		
Lower	*Ostrea*	Grange Burn, near Hamilton
Upper	*Ostrea*	Maretimo member, Whaler's Bluff formation, Portland
Lower	*Glycymeris*	Muddy Creek, near Hamilton
Miocene		
Upper	*Ostrea*	Beaumaris
Middle	*Ostrea*	Bairnsdale
Upper	*Glycymeris*	Beaumaris
Lower	*Glycymeris*	Balcombe Bay
Upper	*Chlamys*	Beaumaris
Middle	*Chlamys*	Bairnsdale
Lower	*Chlamys*	Balcombe Bay
Oligocene	*Ostrea*	Waurn Ponds, near Geelong
Oligocene	*Glycymeris*	Jan Juc formation, Torquay
Oligocene	*Chlamys*	Jan Juc formation, Torquay
Oligocene	*Chlamys*	Waurn Ponds, near Geelong
Eocene		
Upper	*Notostrea*	Brown's Creek, Cape Otway district
Upper	*Notostrea*	Hamilton Creek, Cape Otway district
Upper	*Seripecten*	Hamilton Creek, Cape Otway district
Paleocene	*Lahillia*	Pebble Point, Otway Coast

Figure 1 summarizes the results obtained for the Tertiary fossils. It shows a rise in temperature in the first half of the Tertiary and a fall in the second half. This is in keeping with the biological evidence obtained from the fossils themselves. The Middle Tertiary is characterized by masses of tropical foraminifera such as *Lepidocyclina, Cycloclypeus* and *Carpentaria,* echinoderms such as *Phyllacanthus, Eucidaris* and *Lovenia* and mollusks such as giant cowries and volutes, *Cucullaea* and *Hinnites* (the last two in great numbers). It is not until the Pliocene that the marine fauna is comparable with that living in the same area now. Emiliani (*4*) has also traced this Upper Tertiary fall in temperature for Pacific abyssal waters.

The localities for Pleistocene fossils are the Yarra delta formations (dated in part by radiocarbon), emerged shell beds of the 25-ft eustatic level, and Lower Pleistocene beds (Werrikooian stage) in far western Victoria. The sites which yielded the Tertiary fossils whose paleotemperatures are given in Fig. 1 are tabulated in the legend. Further details are given elsewhere (*5*).

F. H. Dorman
Chemical Research Laboratories, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia

Edmund D. Gill
National Museum of Victoria, Melbourne

References

1. H. C. Urey, H. A. Lowenstam, S. Epstein, C. R. McKinney, *Bull. Geol. Soc. Am.* **62**, 399 (1951); C. R. McKinney, J. McCrea, S. Epstein, H. Allan. H. C. Urey, *Rev. Sci. Instr.* **21**, 724 (195(→ S. Epstein, R. Buchsbaum, H. Lowenstam, H. C. Urey, *Bull. Geol. Soc. Am.* **64**, 1315 (1953).
2. S. Epstein and H. Lowenstam, *J. Geol.* **61**, 424 (1953).
3. H. Lowenstam and S. Epstein, *ibid.* **62**, 207 (1954).
4. C. Emiliani, *Science* **119**, 853 (1954).
5. F. H. Dorman and E. D. Gill, *Proc. Roy. Soc. Victoria* **71**, No. 1, 73 (1959).

26 May 1959