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162. THE OSTRACODE GENUS *CYTHERELLOIDEA*, A POSSIBLE INDICATOR OF PALEOTEMPERATURE

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Invertebrate fossils have been used as a means of interpreting paleotemperatures since Neumayr's work on climatic zones of the Jurassic and Lower Cretaceous. Neumayr (1883, p. 283), in turn, refers to earlier workers such as Römer (1852, p. 20–26) who mentioned the climatic influence on the distribution of rudistids. Accumulated paleoclimatological data recently have been summarized by Nairn (1961) and by Schwarzbach (1961).

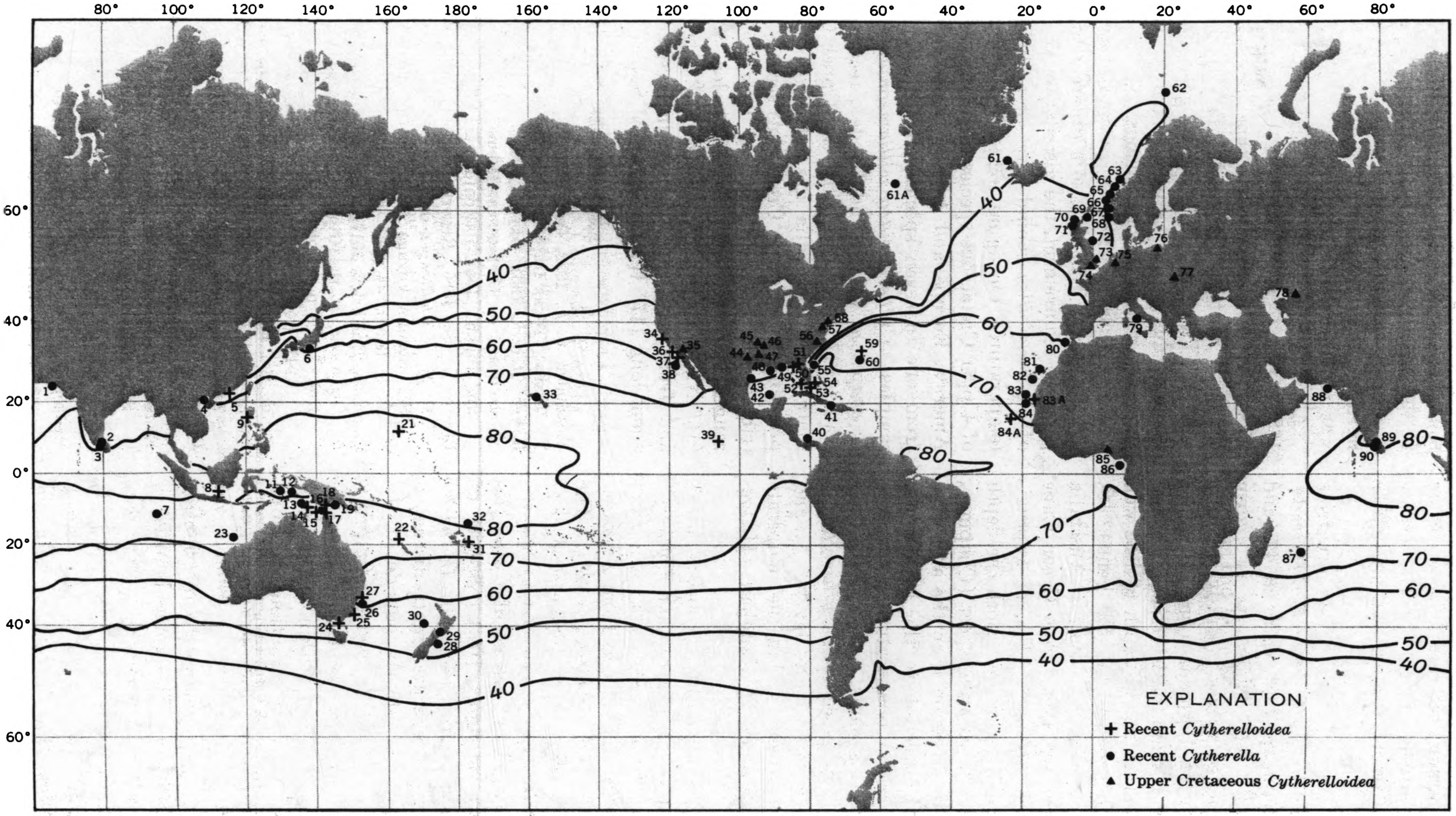
Data are here recorded for an ostracode genus known from the Jurassic to Recent. Because paleotemperature interpretations from other sources are available for the Upper Cretaceous, data for Upper Cretaceous and Recent species of this genus are presented.

As with other organisms the distribution of marine ostracodes is controlled in part by temperature. Living representatives of this subclass are recorded from a minimum temperature of 0.0°C (32°F) at 1,900 fathoms (Brady, 1880, p. 29) to 31°C (87.8°F) at depths of less than a fathom (Kornicker, 1961, p. 59). Except for Elofson's (1941, p. 442–455) and Neale's (1959, 1961) works on Pleistocene and Recent boreal forms, precise data on temperature ranges of individual taxa are not published. A statement by Kornicker (1962), that representatives of the family Cytherellidae from the Bahama Banks would probably not survive at or below 13°C (55.4°F) for extended periods, suggested the research upon which this preliminary report is based.

I am grateful to Dr. L. S. Kornicker, Texas Agricultural and Mechanical College, for sending me a copy of the typescript of his forthcoming report; to Prof. Edwin C. Allison, San Diego State College, Calif., for unpublished information on ostracodes near Clipperton Island (fig. 162.1, loc. 39), and to one of his students, John C. Holden, for information on an Upper Cretaceous species of *Cytherelloidea* in California.

The genus *Cytherelloidea* was erected by Alexander (1929, p. 55) to segregate species with ornamented shells from the marine benthonic species that were previously assigned to *Cytherella* Jones (1849, p. 28). Published descriptions and illustrations of all the living species of *Cytherella* were examined in order to determine which species actually belong to *Cytherelloidea*. The localities from which living species of *Cytherelloidea* have been recorded, and a few unpublished occurrences, are shown on figure 162.1.

Superposition of calendar-month isocrymes of surface-water temperature (Hutchins and Scharff, 1947, pl. 2) on this map limits the distribution of living species of *Cytherelloidea* to areas having a minimum temperature of approximately 10°C (50°F). Calendar-month isocrymes as defined by Hutchins and Scharff (1947, p. 266) are isotherms that connect points which cool down to the same extremes as measured in monthly mean temperatures. Although *Cytherelloidea* is a benthonic genus, a correction due to the decrease of temperature with depth is not made



Base from US Navy Hydrographic Office chart 1262b, July 1941

FIGURE 162.1.—Map showing the distribution of living species of *Cytherelloidea* and *Cytherella* and Upper Cretaceous species of *Cytherelloidea*, and calendar-month isocrymes (degrees Fahrenheit) from Hutchins and Scharff (1947).

because precise data are not available. The error introduced by this fact is negligible, however, because most of the species are recorded from shallow depths to 46 fathoms.

Only two species of *Cytherelloidea* are known from depths lower than 46 fathoms. *C. irregularis* (Brady, 1880) and *C. auris* Chapman, 1941, occur at 435 and 470 fathoms respectively. *C. irregularis* is known from "one or two detached valves" (Brady, 1880, p. 178) from the vicinity of Bermuda (fig. 162.1, loc. 59) where the isocryme is close to 21.1°C (70°F), and any decrease of temperature due to depth will be well above the minimum determined for the genus. *C. auris* is recorded from the southeast coast of Australia (loc. 25) at 33 miles east by south from Green Cape (lat 37°21′20″ S., long 150°24′25″ E.), at approximately the 12.8° C (55°F) isocryme. Both the depth and the location of this record are suspect (Chapman, 1941, p. 152) because the location is in the area of a steep slope. A slight correction to the west would place this species in bottom temperatures above the minimum postulated for this genus.

The distribution of living species of *Cytherelloidea* is bounded roughly by lat 40° S. and lat 37° N., and by the 10°C (50°F) isocryme, within the temperate and tropical biogenetic zones of Vaughan (Hedgepeth, 1957, p. 364).

The genus *Cytherella* appears to tolerate much wider temperature and depth ranges than *Cytherelloidea. Cytherella lata* Brady, 1880, is known from 675 fathoms (Brady, 1880, p. 15) and from a bottom temperature of 4.9°C (40.8°F) (idem., p. 23). The geographic range of this genus is from the equatorial region to the Arctic lat 73° N..

Localities from which living species of *Cytherella* are recorded are shown on figure 162.1. Species of *Cytherella* are associated with species of *Cytherelloidea* only within the temperature limits discussed, but *Cytherella* is found consistently outside of the minimum temperature limits determined for *Cytherelloidea*, suggesting that temperature is probably the major factor that controls the distribution of *Cytherelloidea.* Additionally, this distribution supports Alexander's separation of *Cytherelloidea* as a genus distinct from *Cytherella.*

Douglass (1960, text fig. 1) shows the distribution of the foraminifer *Orbitolina.* This genus is inferred to have lived in tropical and subtropical waters having a temperature range of 15°C to 35°C (59°F to 95°F). The northernmost record for Upper Cretaceous species of *Orbitolina* is from southern England, about lat 51° N. or about 3½° of latitude farther south than species of *Cytherelloidea* of the same age. It therefore seems consistent that the probable minimum temperature during Late Cretaceous time at the northern limit from which *Cytherelloidea* is recorded was not less than 10°C (50°F).

A temperature range for Western Europe of about 15°C to 21°C (59°F to 70°F) for the Maestrichtian was inferred by oxygen isotope methods by Lowenstam and Epstein (1954 p. 226, fig. 10), and by Bowen (1961). This range inferred by geochemical methods is compatible with the minimum temperatures inferred above by paleontologic methods.

If the basic assumption is correct that the genus did not adapt with time to a different minimum temperature requirement, the distribution of fossil species of *Cytherelloidea* should give some clues as to paleotemperature. On figure 162.1 are shown the locations of Upper Cretaceous species of this genus from North America, Europe, and Africa. Each point represents from one to seven species, and from one to several samples. *Cytherelloidea williamsoniana* (Jones) and *C. chapmani* (Jones and Hinde), recorded by Chapman (1917, p. 51, 52) from the Upper Cretaceous of southwestern Australia, are not used because they are probably from Lower Cretaceous sediments. The distribution of the genus during Late Cretaceous time ranged from Nigeria (fig. 162.1, loc. 85), about lat 6½° N., to North Germany (loc. 76), about lat 54° N., and from about long 55° E. in Russia (loc. 73) to about long 117° W. in the United States (loc. 35).

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SEDIMENTATION

163. WIND DIRECTIONS IN LATE PALEOZOIC TO MIDDLE MESOZOIC TIME ON THE COLORADO PLATEAU

By F. G. Poole, Denver, Colo.

Work done in cooperation with the U.S. Atomic Energy Commission

The cross-stratified eolian sandstones of late Paleozoic to middle Mesozoic age on the Colorado Plateau are here divided into four major age groups: (a) the Weber Sandstone, of Pennsylvanian and Permian age, the White Rim, Cedar Mesa, and De Chelly Sandstone Members of the Cutler Formation, and the De Chelly and Coconino Sandstones, of Permian age; (b) the Wingate Sandstone and tongues of Wingate Sandstone in the upper part of the Chinle Formation, of Late Triassic age, and the Dinosaur Canyon Sandstone Member of the Moenave Formation, of Late Triassic(?) age; (c) the Nugget Sandstone, of Early Jurassic age, Navajo Sandstone, of Jurassic and Triassic(?) age, and Aztec Sandstone, of Jurassic(?) age, and tongues of Navajo Sandstone in the Kayenta Formation, of Late Triassic(?) age; and (d) the Carmel Formation, of Middle and Late Jurassic age, and the Entrada, Bluff, Junction Creek, and Cow Springs Sandstones, of Late Jurassic age. No correlation or stratigraphic position of these subunits is implied within the four major groups.

The portions of the sandstone units described in this paper are interpreted as dominantly eolian, although they contain some fluvial or marine strata, because their lithology and sedimentary structures are physically similar to modern dune deposits. Only a small proportion of the Weber, Dinosaur Canyon, and Carmel is considered eolian. The sandstones are, in general, light colored and are composed chiefly of quartz grains with subordinate amounts of feldspar, chert, and clay minerals. The bonding medium for the grains consists both of silica cement, in the form of quartz overgrowths and microcrystalline quartz, and of carbonate cement. Grains range in size from very fine to coarse sand, with fine sand usually predominating. Most of the sandstones are moderately to well sorted. Sand grains range from subangular to well rounded; the larger grains are generally the better rounded. Pitting and frosting of the grains are common.

Sedimentary structures consist of wedge-planar and subordinate tabular-planar, lenticular-trough, and lenticular-simple sets of cross strata. The lower boundary of a planar set is a plane surface of erosion; the lower boundary of a trough set is a curved surface of erosion; and the lower boundary of a simple set is a nonerosional surface (McKee and Weir, 1953). The deposits are composed almost exclusively of steeply