Temperature and Salinity Control of the Concentration of Skeletal Na, Mn, and Fe in *Dendraster excentricus*[1]

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SPECIMENS OF *Dendraster excentricus* (Eschоltz), the common American Pacific coast sand dollar, were collected from 22 localities between mid Baja California and Vancouver Island (Fig. 1). Three tests from each of the 22 localities were analyzed for Na, Mn, and Fe, using an atomic absorption spectrophotometric technique. Fe was determined with an analytical precision of $\pm 3.0\%$ of the amount present. Mn was determined to $\pm 2.0\%$ and Na to $\pm 8.0\%$. Table 1 is a summary of the analytical results. (Chemical analyses were made in the Department of Geology, Rice University.)

The primary purpose of this investigation is to delineate the effects of the environmental parameters, temperature and salinity, on the skeletal concentration of Na, Mn, and Fe in *D. excentricus*. Such information can be of interest both from the standpoint of paleoecology and in the elucidation of calcification processes. Because a single monomineralic species was studied, mineralogical and physiological variables affecting test composition are relatively constant and environmental factors are emphasized. A second purpose is to contribute knowledge of the concentration of Na, Mn, and Fe in natural high-Mg calcites, about which little is known.

Previously Pilkey and Hower (1960) studied the Sr and Mg contents of tests of the same species of sand dollar. The Mg contents of *D. excentricus* tests appeared to be directly related to both temperature and salinity. The Sr content is inversely related to temperature and is unaffected by salinity.

Environmental data used in the present study are approximations based on extrapolation of data from points of known water conditions to specific collecting localities. Considerably more data on temperature than on salinity were available for this purpose. Unfortunately, it was possible to obtain low salinity specimens only at the end of the temperature range, which prevents observation of salinity effects over a wide temperature range.

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RESULTS

Figure 2 is a plot of the Na, Mn, and Fe content of *D. excentricus* tests vs. the mean summer temperature (mean temperature of the three warmest months at the various collecting localities). This measure of water temperature was chosen because in the previous study (Pilkey and Hower, 1960) the closest temperature-composition correlations were noted with reference to summer temperatures. Each point on Figure 2 represents an average concentration value based on analyses of three individual tests from each location. Because of the lack of precise salinity data, locations were classified simply as normal or low salinity. (For present purposes, low salinity is arbitrarily considered to be less than 32 ppt.) Normal and low salinity locations are designated by separate symbols in Figure 2. A third symbol is used for analyses of bay or quiet water forms which are recognized as a separate "ecological race" (Raup, 1958). All of the bay forms are also from low salinity locations. The trend lines in Figure 2 are least squares regression lines calculated using all of the data.

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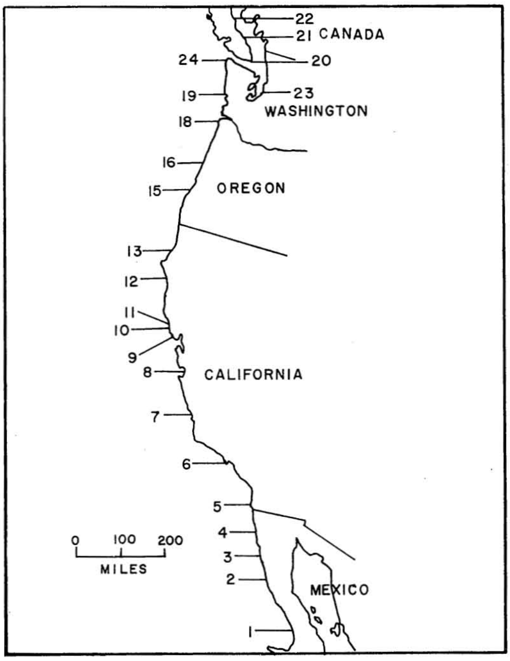

FIG. 1. Map showing approximate position of collecting localities.

Individual analyses of Na in *D. excentricus* tests ranged from 3,800 to 12,200 ppm, averaging 6,440. Mean values of three tests from each locality range from 4,100 to 10,600 ppm. Very few analyses of Na in the skeletons of other organisms are available for comparison with these data. The low-Mg calcite shells of the common oyster, *Crassostrea virginica,* generally contain between 2,000 and 3,000 ppm Na, which is somewhat lower than that observed in high-Mg calcite sand dollar tests. A direct relationship between the Na content and salinity was observed in oyster shells by Rucker and Valentine (1961), but this was not observed in sand dollars (Fig. 2); however, the oysters were collected over a much wider range of salinities.

The Mn content of *D. excentricus* tests range from 12 to 91 ppm and averages 35 ppm. The average concentration of the three tests from each locality ranges from 13 to 84 ppm. Figure 2 shows that the lowest values of Mn are found in tests from cold waters; the cold-water tests also exhibit the greatest variation in Mn content. Salinity does not appear to affect the Mn content consistently. Judging from the few published figures on Mn in organic carbonate materials, the high-Mg calcite skeleton of *D. excentricus* contains Mn in intermediate amounts, i.e., lower than some figures reported for low-Mg calcite skeletons, higher than those reported for some aragonite skeletons (Rucker and Valentine, 1961; Pilkey and Goodell, 1963).

The Fe content of *D. excentricus* tests ranges from 140 to 620 ppm and averages 270 ppm. Location averages range from 187 to 573 ppm. Again, no strong temperature or salinity effect is apparent (Fig. 2). The concentration level of Fe in *D. excentricus* tests is similar to that noted in both low-Mg calcite and aragonitic skeletons of other organisms.

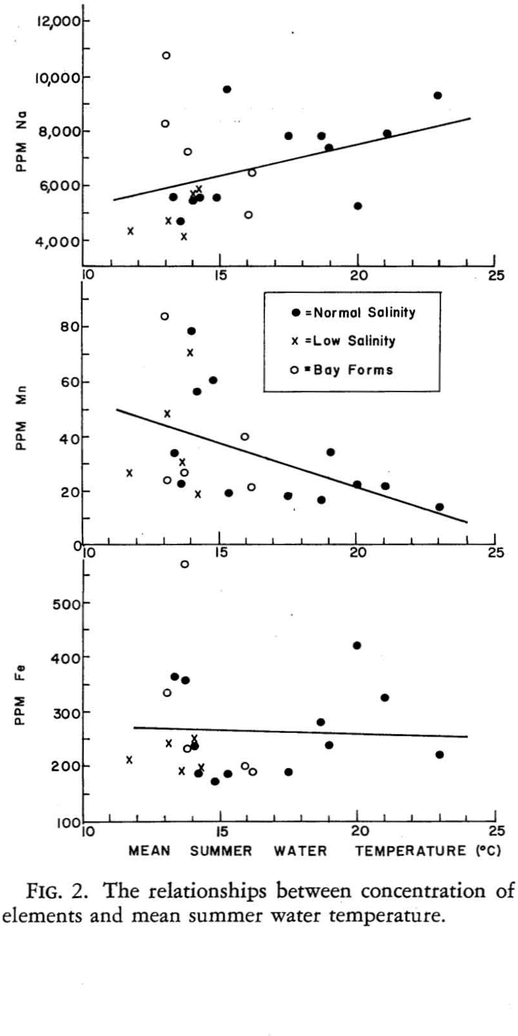

FIG. 2. The relationships between concentration of elements and mean summer water temperature.

TABLE 1

SUMMARY OF ANALYTICAL DATA

LOCATION NO.	Na	Mn	Fe	LOCATION NO.	Na	Mn	Fe
1	8,200*	12	160	12	4,900	18	430
1	9,400	14	230	12	4,200	21	380
1	10,000	14	260	12	4,500	19	260
2	6,800	15	320	13	5,000	60	340
2	6,100	15	280	13	4,500	44	200
2	10,400	15	240	13	4,200	40	200
3	7,200	18	160	15	4,000	31	140
3	8,400	18	200	15	4,000	30	180
3	7,800	19	200	15	4,400	31	270
4	7,200	21	320	16	5,700	20	160
4	8,400	22	340	16	4,900	18	260
4	7,800	21	320	16	5,400	22	190
5	5,500	18	310	18	5,800	70	160
5	5,000	19	440	18	4,500	47	220
5	4,900	22	520	18	5,000	64	140
6	9,000	45	240	19	5,300	59	240
6	6,000	26	240	19	5,700	44	180
6	7,000	27	230	19	5,400	65	150
7	12,200	16	220	20	9,200	25	350
7	9,200	19	160	20	7,200	22	320
7	7,000	31	190	21	8,000	19	190
8	5,300	64	230	21	5,700	21	200
8	6,200	72	270	21	5,300	23	180
8	5,300	77	260	22	5,400	40	220
9	5,700	57	300	22	4,500	35	140
9	5,700	82	200	22	4,300	46	260
9	4,900	94	220	23	9,800	91	620
10	6,000	23	230	23	12,200	86	480
10	8,000	27	260	23	9,800	74	620
10	7,600	31	190	24	4,900	26	270
11	5,800	34	350	24	3,800	29	150
11	4,500	32	320	24	4,000	27	230
11	6,200	35	420				

* All quantities expressed as ppm.

DISCUSSION

Linear correlation coefficients were calculated for the relationships between composition and water temperatures. When using all the data, only the inverse Mn relationship is barely significant (95% confidence level). Removal of the bay forms from consideration results in a strong significant direct relationship between Na content and water temperature, but has little effect on the Mn curve. The Fe content exhibits no significant relationship with temperature.

Distinct interpopulation differences in the concentration of these elements exist, but it is apparent that differences in temperature and salinity are only partially responsible for these compositional differences. Other previously cited trace element studies of individual species, in which environmental effects were observed, also indicate that temperature and salinity differences are only partly responsible for compositional differences. Part of the problem in this and in the other studies has been the difficulty in estimating reliably the natural environmental conditions under which skeletal material was deposited. Furthermore, it may well be that presently unevaluated metabolic and crystal growth effects (which may or may not be related to external environmental conditions) are important factors in the distribution of skeletal trace elements.

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