FAUNAL RELATIONSHIP TO GRAIN-SIZE, MINERALOGY AND GEOCHEMISTRY IN RECENT TEMPERATE SHELF CARBONATES, WESTERN TASMANIA, AUSTRALIA

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ABSTRACT: In western Tasmania cool temperate shelf carbonates predominate over siliciclastics and contain mainly bryozoan-mollusca-foraminifera assemblages with minor algae, echinoderms, worm tubes, sponge spicules and ostracodes. Skeletons are mainly in gravel to sand fractions and minor in silt-clay fractions. Bryozoans are the main constituent in sand to gravel-size, foraminifera are the main constituent in fine sand-size and molluscans are mainly in the gravel-size fraction. Echinoderms and algae are in sand fraction, whereas sponge spicules occur in fine to very fine sand fractions.

X-ray analysis of Tasmanian bulk sediments indicate that calcite (high-Mg to low-Mg calcite; mean 69%) and quartz (mean 22%) are the major minerals with minor aragonite content (mean 9%). Mg, Sr, and Na contents in bulk sediments are positively related to high-Mg calcite bryozoans. Sr and Na contents exceed abiotic calcite values due to biotic source of these elements. Compared to tropical bryozoans, the higher Sr contents in Tasmanian bryozoans indicate a higher rate of bryozoan skeletal formation in temperate waters. Mn and Fe contents of bulk sediments are closely correlated with r^2 value of 0.85. These elements are derived mainly from terrigenous source and were incorporated into calcite in a dysaerobic marine environment.

Tasmanian temperate bryozoan faunal assemblages differ from tropical chlorozoan assemblages due to variation in seawater temperatures. Bryozoans break down into fragments and are redistributed mainly as gravel to sand-size grains by currents. Normal salinity of seawater (34-35‰) and nutrients in temperate waters allow abundant growth of fauna. Mixing of water masses maintain sufficient saturation of $CaCO_3$ and thus preserve temperate carbonates.

INTRODUCTION

Extensive modern temperate shelf carbonates are now forming in a number of areas (Lees 1975; Nelson 1988 and references therein), particularly along the southern Australia. In Tasmanian seas, cool temperate carbonates predominate over siliciclastics (Fig. 1). Based on uniformitarian principles, we should expect to find similar widespread temperate carbonates in the rock record, but only a few examples have so far been documented (e.g., Nelson 1978; Brookfield 1988; Draper 1988; Rao 1988a; James and Bone 1989, 1992). The possible occurrence of extensive ancient temperate carbonates is abundantly indicated by types of biota and non-skeletal grains, original calcite mineralogy, and elemental and isotopic composition of carbonates (Rao and Jayawardane 1994).

Modern temperate shelf carbonates are composed mainly of skeletal grains with variable amounts of intragranular cements (Rao 1981a). The fauna are either foraminifera and molluscan assemblages (Foramol assemblages; Lees 1975) or bryozoan and molluscan assemblages (Bryomol assemblages; Nelson 1978, 1988). This discrepancy in the predominant faunal assemblage might be due to lack of quantitative determinations of fauna and their relationship to sediment grain-size variation. Relationship of fauna to grain-size is necessary to determine depositional environments and palaeoecology. Many Palaeozoic limestones contain abundant foraminifera, bryozoans and echinoderms (Wilson 1975) similar to modern temperate carbonates. These can be better understood by comparing with modern temperate carbonates: for example Paleozoic limestones that are not associated with warm-water indicators (such as chlorozoan assemblages, non-skeletal grains, aragonite and evaporites) could be of non-tropical origin. Carbonate mineralogy of shallow marine fauna varies with water temperatures: aragonite and high-Mg calcite dominate at temperatures >25°C and mainly high-Mg to low-Mg calcite occurs at <25 to 6°C (Morse and McKenzie 1990; Rao 1993a) and mainly low-Mg calcite occurs at <5°C (Rao 1981b). Major and minor elements (Rao 1986; 1990a; Rao and Adabi 1992) and O and C isotopes (Rao and Nelson 1992; Rao 1993a) of individual fauna and bulk temperate carbonates vary with the type of fauna, mineralogy and water temperatures. The present study aims to delineate quantitatively types of fauna and their relationship to sediment grain-size and bulk mineralogy and geochemistry of temperate carbonates from western Tasmania, Australia (Fig. 1).

METHODS

Surface-sediment samples (Fig. 1) were collected during 1973 on a 10-n mile grid (Davies and Marshall 1973). Sample numbers refer to original numbers given by BMR cruise members (Davies and Marshall 1973) and sediments are stored at AGSO, Canberra and Department of Geology, University of Tasmania. Geographic location and sample depths are listed in Davies and Marshall (1973) publication. Samples studied here are from 30 to 130m water depths.

Samples were sieved and weight per cents were determined on gravel (>2 mm), sand (<2 mm to 250 μ) and fine sand (<250 μ) fractions. In different size fractions more than 100 grains were counted separately for all particles (fauna and grains) and all fauna (fauna only) using a 2mm square

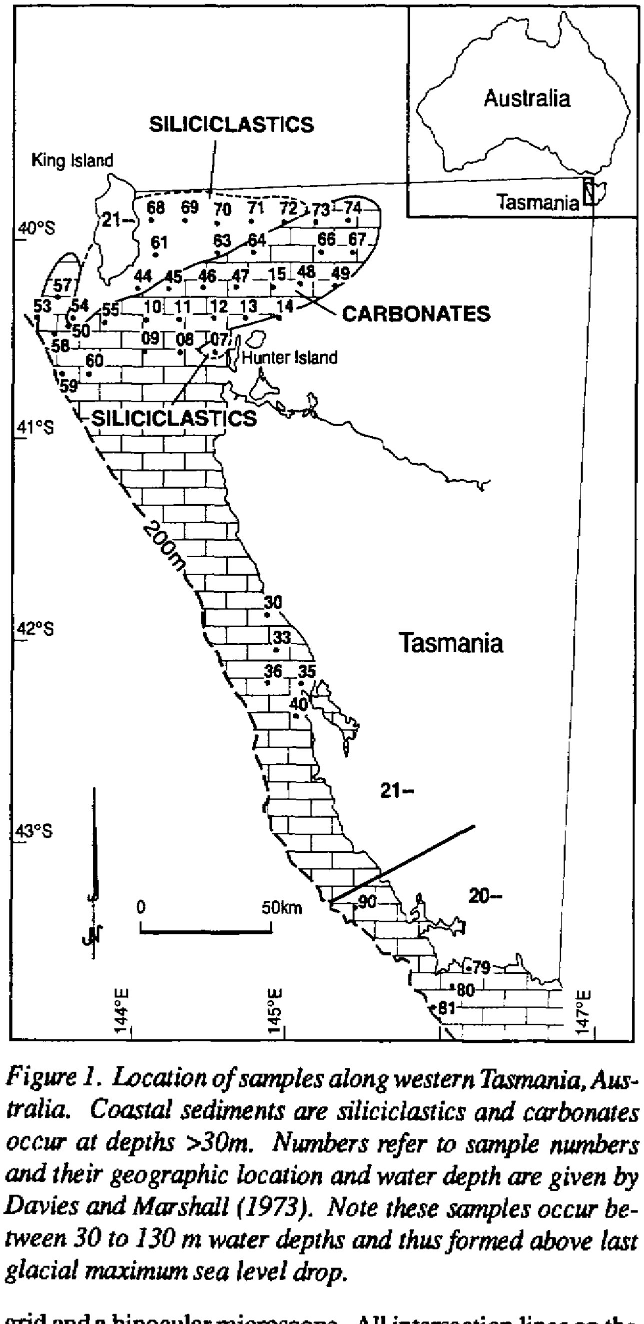

Figure 1. Location of samples along western Tasmania, Australia. Coastal sediments are siliciclastics and carbonates occur at depths >30m. Numbers refer to sample numbers and their geographic location and water depth are given by Davies and Marshall (1973). Note these samples occur between 30 to 130 m water depths and thus formed above last glacial maximum sea level drop.

grid and a binocular microscope. All intersection lines on the grid corresponding to each grain were counted to determine percents. Since area occupied by each grain on the grid is considered in the calculations, these determinations approximate volumetric per cent estimates and thus are suitable to compare grain types with bulk sediment major and minor elements. Major (Ca and Mg) and minor (Sr, Na, Mn, and Fe) elements of bulk sediments were determined by Atomic Absorption Spectrometry on overnight acid digested (1N HCL) carbonate solutions. Percent estimates of calcite, aragonite and quartz were determined from X-ray diffraction analysis using the procedure of Rao and Jayawardane (1993). Factor analysis was performed on data using the Statview programme on a Macintosh computer. Data are stored at Department of Geology, University of Tasmania and will be available upon request.

RESULTS

Petrography

Mean, minimum and maximum petrographic values of 44 bulk samples of western Tasmanian biota, skeletal debris, quartz and rock fragments (Table 1) show that bulk composition of temperate carbonates contain mainly fauna (78.9%) with minor flora (3.7%). Bryozoans (mean, 33.8%) are the predominant fauna with minor amounts of bivalves (8.1%), foraminifera (7.6%), echinoderms (3.5%), gastropods (2.7%), worm tubes (2.4%), sponge spicules (1.4%) with rare amounts of ostrocodes (1%), monoplacophria (0.8%), brachiopods (0.5%), crustaceans (0.4%) and fish (0.5%). Thus, the Tasmanian fauna are bryozoan-mollusca-foraminifera assemblages. Mineralogy of main groups of biota is high-Mg to low-Mg calcite for bryozoans, foraminifera and echinoderm assemblages (mean, 70.4%); aragonite and calcite for gastropod and bivalve or molluscan assemblages (18.9%); silica and calcite for sponges, algae and brachiopods (10.8%). The main siliciclastics are quartz (mean 14.2%) and rock fragments (4.2%).

Factor analysis of petrographic data indicates that 6 factors account for 75% of the total variance (Table 2). Factor 1 is positively related to total amount of "bryozoans, foraminifera and echinoderms" (0.82), water depth (0.64), bryozoans% (0.57) and relative per cent of bryozoans (0.56) and it is inversely related to the total amount of "gastropods and bivalves" (-0.88), relative per cent echinoderms (-0.65) and bivalves (-0.60). Thus, the factor 1 is related mainly to faunal assemblages. Factor 2 is positively related to relative per cent of foraminifera% (0.74), sand% (0.69) and quartz% (0.56) and it is inversely related to relative per cent of bryozoans (-0.74), gravel (-0.72) and bryozoans% (-0.56). Factor 3 is positively related to fines% (<63 μ; 0.86), carbonate mud% (0.86) and fine sand% (63 μ to 250 μ; 0.80). Factor 4 is positively related to benthic foraminifera% (0.63), water depth (0.56) and bivalves% (0.50) whereas factor 5 is positively related to total amount of sponge spicules, rotaliids and bivalves (0.63) and algae% (0.52). Factor 6 is positively related only to echinoderms% (0.86).

Strong inverse relationship with r^2 value of 0.93 exists between total amounts of "bryozoans, foraminifera and echinoderms" and those of "gastropods and bivalves" (Fig. 2) because other fauna occur in minor amounts in Tasmanian carbonates and bryozoans, foraminifera and echinoderms are of calcite whereas gastropods and bivalves are mainly of aragonite.

Grain-size

Grain-size analysis of 44 bulk Tasmanian sediments (Fig. 3) indicates that sand (<2 mm to 250 μ) is the dominant fraction (64%) with subordinate amounts of fine sand (<250 μ; 20%) and gravel (>2 mm; 16%); silt and clay fractions are

Table 1. Percent mean, minimum and maximum values of biota, skeletal debris, quartz, rock fragments and elemental composition in 44 modern Tasmanian bulk temperate carbonates.

Component (%)	Mean	Minimum	Maximum
BIOTA			
Bryozoans	33.8	3	74
Skeletal debris	15.5	2	42
Bivalves	8.1	0	80
Forams	7.6	0	29
Rotaliids	4.7	0	15
Miliolinids	1.8	0	6
Planktonics	1.1	0	8
Algae	3.7	0	16
Echinoderms	3.5	0	11
Gastropods	2.7	0	19
Worm tubes	2.4	0	7
Sponge specules	1.4	0	9
Ostrocodes	1.0	0	5
Monoplacopharia	0.8	0	8
Brachiopods	0.5	0	3
Crustaceans	0.4	0	5
Fish	0.5	0	2
Bryozoa + foraminifera + echinoderms	70.4	8	90
Gastropods + bivalves	18.9	0	22
Sponges + algae + brachs	10.8	0	26
SILICICLASTICS			
Quartz%	14.2	0	85
Rock fragments%	4.2	0	30
ELEMENTAL COMPOSITION			
Ca%	29.3	18.4	36.7
Mg%	1.2	0.4	2.2
Na ppm	2586	1072	4238
Sr ppm	2155	968	3142
Fe ppm	2175	556	7692
Mn ppm	62	22	200

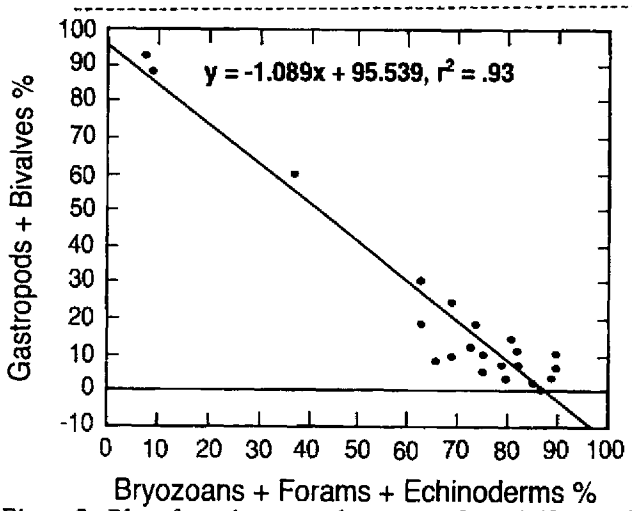

Figure 2. Plot of total contents bryozoans, foraminifera and echinoderms versus total contents of gastropods and bivalves.

minor. The Tasmanian sediments are mixtures of skeletons and skeletal debris with variable amounts of siliciclastics, mainly quartz and rock fragments. Skeletons are mainly in fractions of sand (>180 μ) and fine sand (>125 μ to 180 μ) with minor in very fine sand (<125 μ) fractions. Skeletal debris comprises of broken skeletal fragments whose origins are not always recognizable. Quartz and rock fragments range from gravel to very fine sand fractions.

Relative per cent of bryozoans, foraminifera and mollusca in all particle counts (Fig. 4) shows that bryozoans are the predominant fauna in 74% of the samples studied. Bryozoans mainly occur in the sand to gravel-size fraction, foraminifera in the fine sand-size fraction, whereas molluscans mainly in the gravel-size fraction. The bryozoan-molluscan assemblage is mainly in gravel-size, whereas bryo-

Table 2. Unrotated factor matrix of petrographic data from western Tasmanian samples. R.P. refers to relative per cent between bryozoans, foraminifera and echinoderms. Factor matrix positive or negative values greater than 0.5, shown in bold, indicate statistically significant variables extrated by factor analysis.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Depth,m	**.638**	.036	-.209	**.562**	-.147	.189
Bryozoa%	**.572**	**-.557**	-.102	.050	-.252	-.167
Bryozoans+ Foraminifera + echinoderms %	**.822**	-.094	.039	-.385	-.248	.039
Sponges+ Rotaliids + Bivalves%	.436	**.530**	.054	.011	**.631**	-.115
Gastropods + Bivalves%	**-.878**	-.071	-.051	.348	.039	-.001
RP Bryozoans%	**.564**	**-.74**	-.119	-.12	.226	.028
RP Foraminifera %	-.408	**.737**	.105	.305	-.256	-.236
RP Echinoderms %	**-.647**	.374	.09	-.377	-.043	**.475**
Gravel %	-.45	**-.72**	-.249	.07	-.168	.002
Sand%	.418	**.688**	-.435	-.146	-.013	.041
Fine sandt%	.059	.08	**.801**	.086	.171	-.051
Fines (<63μ) %	.066	-.091	**.860**	-.142	-.09	-.071
Algae%	.46	.143	-.271	.107	**.518**	.083
Bivalves%	**-.603**	-.311	.030	**.502**	.133	.187
Echinoderm %	.116	.048	.097	-.398	-.075	**.86**
Benthic Foraminifera %	.271	.428	.067	**.630**	-.155	.204
Planktonic Foraminifera %	.378	.140	.270	**.568**	-.179	.302
Gastropods %	-.462	-.466	-.269	-.062	.265	.150
Sponges%	-.103	-.103	.359	.146	**.562**	.099
Quartz%	-.376	**.563**	-.211	**-.506**	-.035	-.184
Carbonate Mud%	.081	-.157	**.860**	-.196	-.074	-.073

zoan-foraminifera assemblage is in sand to very fine sand fractions. The foraminifera and molluscan assemblage is rare in these Tasmanian sediments. Thus, the dominance of a faunal type is related to grain-size of the sediment. The variation of relative per cent of bryozoans, foraminifera and mollusca in all fauna counts is similar to that in all particle counts.

Relative per cent of echinoderms, algae and sponges in all particles (Fig. 5) and in all fauna counts indicate that these faunae occur together in most Tasmanian samples. Sponge spicules predominate over echinoderms and algae in most samples. Echinoderms and algae are in sand fraction, whereas sponge spicules occur in fine to very fine sand fractions.

Mineralogy

X-ray diffraction analysis of bulk sediments (Rao and Adabi 1992; Rao and Jayawardane 1993) indicate that the Tasmanian sediments studied here mainly consist of calcite (high-Mg to low-Mg calcite; mean 69%; range 16 to 97%), quartz (mean 22%; range 0 to 84%) and aragonite (mean 9%; range 0 to 41%). Calcite and quartz contents are inversely related with a significant r^2 value of 0.92 due to relatively uniform aragonite content.

Factor analysis of data comprising of contents of calcite, aragonite and calcite and major and minor elements in bulk sediments along with major fauna indicate four factors (Table 3) account for 75% of total variance. Factor 1 is positively related to values of calcite (0.91), Sr (0.9), bryozoa (0.82), Mg (0.75), Ca (0.73), relative per cent bryozoa (0.67) and water depth (0.52) and inversely related to quartz (-0.94) relative per cent echinoderms (-0.72) and relative per cent foraminifera (-0.6) contents. Factor 2 is positively related to the total amount of gastropods and bivalves (0.97) and inversely to total amount of bryozoans, foraminifera and echinoderms (-0.92). Factor 3 is positively related to Fe (0.84) and Mn (0.79). Factor 4 is positively related to water depth (0.66) and relative per cent foraminifera (0.54).

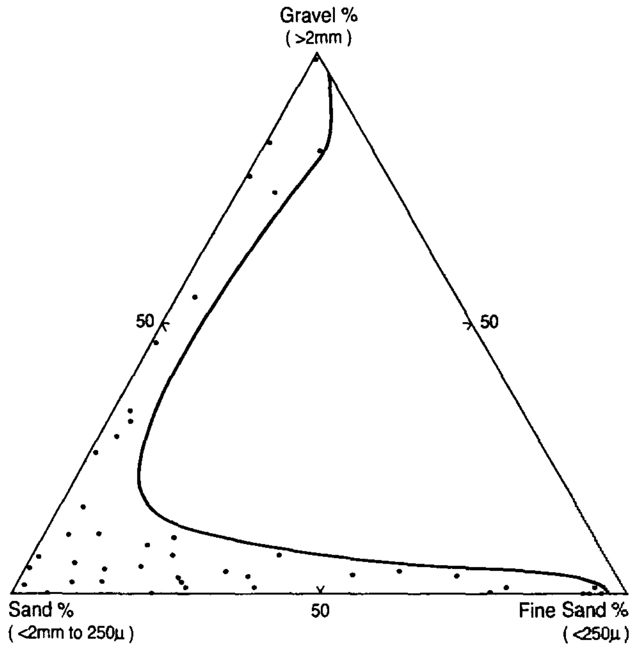

Figure 3. Relative weight per cents of gravel, sand and fine sand fractions in western Tasmanian samples studied.

Geochemistry

In the Tasmanian bulk sediments studied here, the mean and minimum and maximum values for Ca (29.3%; 18.4 to 36.7%), Mg (1.2%; 0.4 to 2.2%), Na (2586 ppm; 1072 to 4238 ppm), Sr (2155 ppm; 968 to 3142 ppm), Fe (2175 ppm; 556 to 7692 ppm), Mn (62 ppm; 22 to 200 ppm) and insoluble residue (16.5%; 1.7 to 49.8%) are due to occurrence of pure to mixed carbonates with siliciclastics. The mean Mg value of 1.2% indicates bulk sediments contain mostly high-Mg calcite. Since modern biotic and abiotic marine calcites have similar range of Mg contents (Carpenter and Lohmann 1992), it may not be possible to differentiate between biotic and abiotic source for Mg in Tasmanian bulk carbonates. Sr and Na contents are positively correlated with a r^2 value of 0.55 (Fig. 6). Sr contents (968 to 3142 ppm) in most of these samples exceed abiotic calcite Sr value of ~1,200 ppm (Carpenter and Lohmann 1992) due to mineralogical and biotic source of Sr in Tasmanian carbonates. Similarly Na contents (1072 to 4238 ppm) are much higher than abiotic calcite Na value of ~230 ppm (Veizer 1983) due to biotic source of Na in Tasmanian carbonates. Since Ca, Mg, Sr, Na and calcite are positively related in factor 1 (Table 3), these elements increase with increasing bryozoan calcite content. Seawater is the source for these elements. Mn and Fe con-

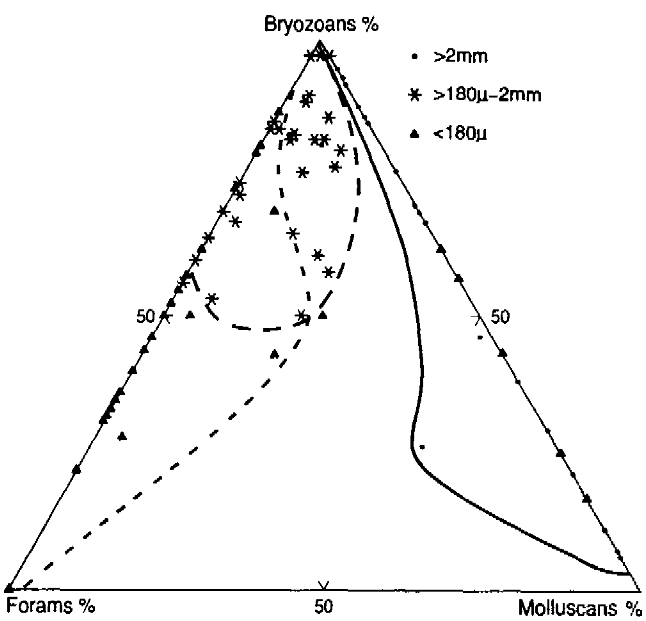

Figure 4. Relative per cents of bryozoans, foraminifera and molluscans in all particle (Fig. 4) and all fauna in western Tasmanian samples studied.

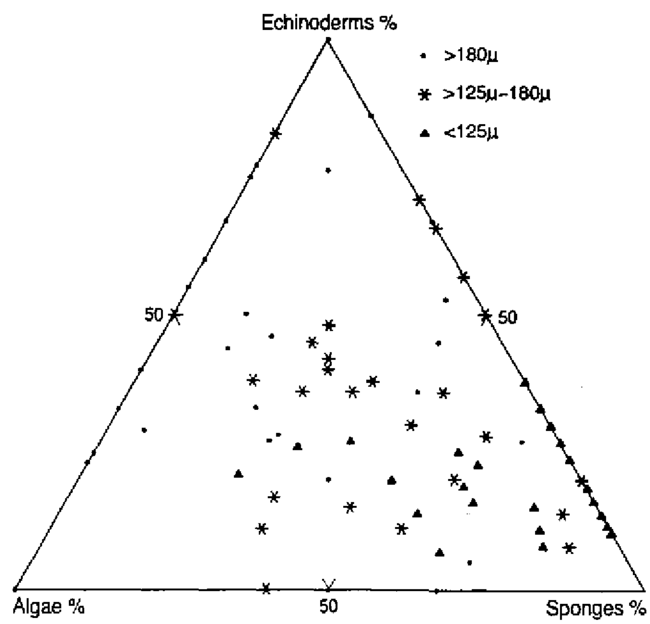

Figure 5. Relative per cent counts of echinoderms, algae and sponges in all particle (Fig. 5) and all fauna in western Tasmanian samples studied.

Table 3. Unrotated factor matrix of petrographic, mineralogical and geochemical data of western Tasmania sample R.P. refers to relative per cent between bryozoans, foraminifera and echinoderms. Factor matrix positive or negative values greater than 0.5, shown in bold, indicate statistically significant variable extrated by factor analysis.

	Factor 1	Factor 2	Factor 3	Factor 4
Depth/m	**.516**	-.255	-.226	**.664**
%Quartz	**-.943**	-.196	.084	-.166
%Calcite	**.913**	.065	.022	.324
%Ca	**.728**	.406	-.348	.364
%Mg	**.748**	-.148	.464	.368
Na ppm	**.733**	.236	-.054	**-.463**
Fe ppm	**.449**	-.077	**.835**	-.182
Mn ppm	**.472**	-.14	**.789**	-.229
Sr ppm	**.896**	.245	-.126	-.108
Bryozoa%	**.819**	-.069	.104	.151
Bryozoans+ Foraminifera + Echinoderms	.125	**-.919**	.079	.06
Sponges+ Rotaliids + Algae	-.316	**-.557**	-.269	.192
Gastropods + Bivalves	-.024	**.967**	.004	-.106
RP Bryozoa%	**.674**	-.322	-.373	**-.497**
RP Foram%	**-.599**	.358	.369	**.544**
RP Echinoderms	**-.722**	.191	.306	.168

tents are positively correlated with a significant r^2 value of 0.85 (Fig. 7). Mn and Fe contents are more closely related to factor 3 than factor 1 (Table 3) in Tasmanian carbonates. Thus Mn and Fe contents are, in part, from terrigenous source and were later incorporated into calcite in a dysaerobic marine environment. Mg contents (Fig. 8) and Sr contents (Fig. 9) are positively related to bryozoans% because of predominance of high-Mg calcite bryozoans in Tasmanian carbonates (Rao and Adabi 1992).

DISCUSSION

Fauna and their relationship to grain-size, mineralogy and geochemistry are mainly related to: 1) seawater temperatures, 2) skeletal formation, 3) sedimentation, 4) water depth and 5) seawater composition

Seawater Temperatures

The Tasmanian temperate faunae are bryozoa-mollusca-foraminifera assemblages and these differ from tropical chlorozoan assemblages (Lees 1975) due to variation in seawater temperatures. Around Australia summer surface seawater temperatures in tropics (<30°S) are >25°C and in cool temperate Tasmania (40 to 44°S) are <19°C (Edwards 1979). In winter surface seawater temperatures around Tasmania are <13°C (Newell 1961) and thus there is a strong seasonal temperature effect (Rao and Adabi 1992). Seawater temperatures drop to ~3°C in deep water (≥ 500 m) around Tasmania (Harris et al 1987; Rao and Huston 1994). The mean Mg content of 1.2% in bulk Tasmanian sediments studied here corresponds to the 15°C of experimental data on variation of Mg with water temperature (Mucci 1987; Burton and Walter 1991). This mean temperature of 15°C is close to Tasmanian sea winter temperatures of <13°C instead of summer temperatures of <19°C. Kolesar (1978) observed Mg content in coralline alga calcite is related to growth rate, which appears to be a function of temperature. During winter the growth rate of coralline alga was rapid and the Mg content in calcite was positively correlated with temperature. During summer the growth rate was slow and Mg in calcite was uncorrelated with temperature. Therefore, the positive correlation between Mg and bryozoa and correspondence of Mg content to maximum winter temperatures in Tasmanian carbonates might be due to rapid growth of bryozoa in winter. Tasmanian $\delta^{18}O$ and $\delta^{13}C$ values indicate western Tasmanian

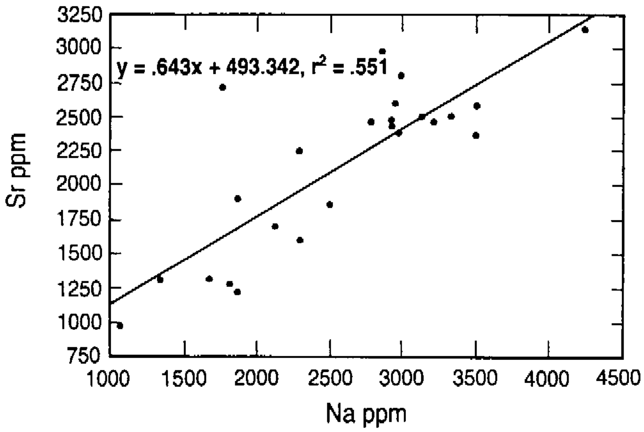

Figure 6. Plot of Sr versus Na contents in bulk samples from western Tasmania.

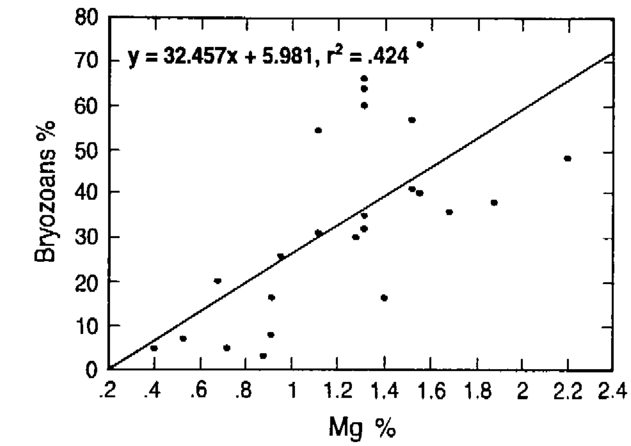

Figure 8. Plot of petrographic bryozoans% versus Mg% of bulk sediments from western Tasmania.

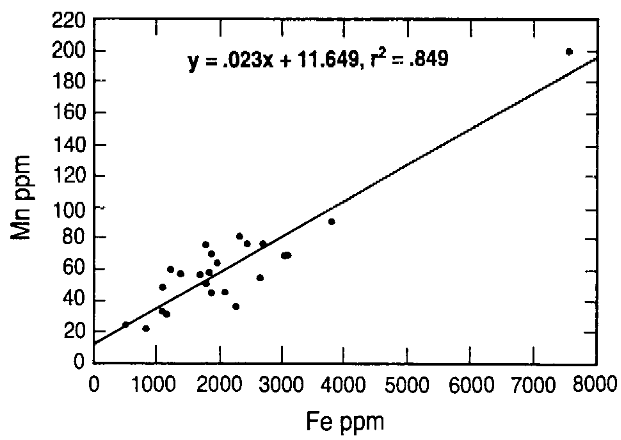

Figure 7. Plot of Mn versus Fe contents in bulk samples from western Tasmania.

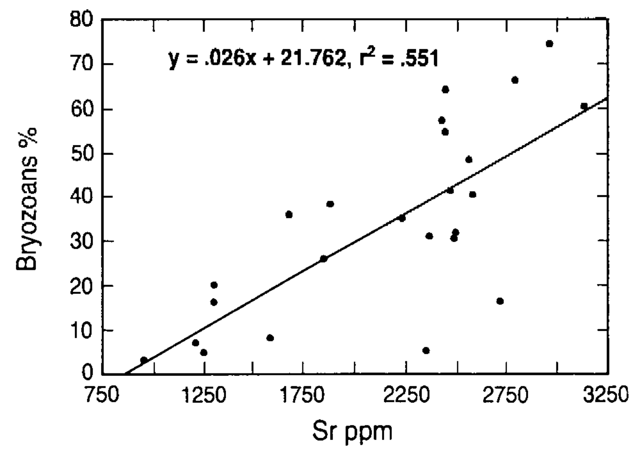

Figure 9. Plot of petrographic bryozoans% versus Sr ppm of bulk sediments from western Tasmania.

bulk carbonates are influenced by cold upwelling deep water (Rao and Green 1983; Rao and Adabi 1992).

Skeletal Formation

Petrographic measurements (Table 1) indicate that bryozoans are the most important sediment producers, followed by bivalves and foraminifera. Since molluscans are the dominant fauna in only 12% of Tasmanian samples studied (Fig. 4), the main fauna in these bulk samples are mixtures of bryozoans and foraminifera. The relative abundance of bryozoans and foraminifera is related to grain size variation of sediment with foraminifera dominating in fine sand and bryozoans in sand and gravel fractions (Fig. 4). Sr values in biotic and abiotic calcites increase with increasing rate of precipitation (Carpenter and Lohmann 1992). The variation of Sr with bryozoan content in western Tasmanian samples (Fig. 9) illustrates that these pure (100%) calcite bryozoans have Sr values ≥3,000 ppm higher than tropical bryozoans (2,400 to 2,900 ppm; Carpenter and Lohmann 1992). Eastern Tasmanian pure high-Mg calcite bryozoans also have Sr values (2,600 to 3,500 ppm) higher than those of tropical bryozoans because the rate of formation of temperate bryozoan skeletal calcite is higher than that of tropical bryozoans.

Sedimentation

Temperate carbonates from Tasmania and along southern Australia are mostly bioclastic with high proportions of bryozoans (Connolly and van der Borch 1967; Wass et al. 1970). Bryozoans break down into fragments upon their death. Initial fragment size depends on growth forms of bryozoans (Bone and James 1993). These grains are subsequently redistributed from the shelf to deep environments and range in size from boulder to mud. In Tasmania bryozoans are most abundant as gravel to sand-size grains (Fig. 4) and are similar to widespread bryozoan sand accumulations in southern Australia (Connolly and van der Borch 1967; Wass et al. 1970). Since the sea along the western Tasmania is one of the roughest in the world, rarity of silt-clay fractions in Tasmanian sediments (Fig. 3) indicates that currents on Tasmanian shelf are powerful enough to sort grains and possibly winnow the finer fractions to greater depths.

Water Depth

The western Tasmanian samples studied here are from water depths of 30 to 130 m and thus formed above the last glacial maximum sea level drop of 130 m. In factor analysis, the negative correlation between water depth and quartz (-0.94) and positive correlation between calcite and water depth (0.93; Table 3) is due to high quartz content mostly limited to the coast and increasing of carbonate content with increasing water depth further offshore. Positive correlation between water depth and relative per cent bryozoan content (0.57) and negative correlation between water depth and bivalves (-0.6) and relative per cent echinoderms (-0.65; Table 2) indicates bivalves and echinoderms occur mainly in shallow depths and bryozoans occur throughout water depths. Since Mg, Sr, and Na values in bulk sediments correspond to bryozoan content and the mineralogy is mainly high-Mg calcite, the sediments studied are unaffected by meteoric diagenesis and thus represent continuous marine sedimentation and marine diagenesis during Holocene. Mg, Sr, and Na values in sediments decrease and high-Mg calcite changes to low-Mg calcite due to meteoric diagenesis (Brand and Veizer 1980; Rao 1990b).

Seawater Composition

Salinity and $CaCO_3$ saturation in seawater affect biota formation and subsequent preservation. In tropical carbonates, such as those from the Persian Gulf, the salinity ranges from about 40 to >100‰ (Purser and Seibold 1973). In temperate Tasmanian seas, the salinity varies between 34.3 and 35.5‰ (Edward 1979; Rao and Huston 1994). Shallow marine fauna live abundantly in normal salinity waters and fauna decrease with increasing salinity of seawater, whereas marine algae are tolerant of higher salinity waters and thus occur in very shallow water to exposed environments. Since the saturation of $CaCO_3$ in seawater decreases with decreasing seawater temperature, vast columns of cold seas in high latitudes are presently undersaturated in $CaCO_3$, and the carbonate sediments in contact with these water are affected by submarine dissolution and breakdown (Alexandersson 1978; Smith et al 1992). On tropical shelves, dissolution of $CaCO_3$ is rare and early marine cementation is common. Dissolution behavior of temperate bryozoan sediments (Smith et al 1992) indicate small delicate forms dissolve away easily whereas large robust colonies are unaffected. In Tasmania, the occurrence of abundant bryozoans, marine cementation (Rao 1981a; 1990a) and the rarity of dissolution features indicate saturation of $CaCO_3$ was maintained by mixing water masses (Rao 1993b; Rao and Huston 1994). Nutrient content in Tasman seawater increases by the introduction of subantarctic water masses in winter around Tasmania (Harris et al 1987). High nutrient content allows luxuriant growth of fauna in temperate seawater.

CONCLUSIONS

In western Tasmania cool temperate carbonates predominate over siliciclastics and comprise reworked skeletal grains. This study on fauna and their relationship to mineralogy, grain-size and geochemistry illustrate the following characteristics of temperate carbonates:

1. Fauna comprise mainly of bryozoan-mollusca-foraminifera assemblages with minor flora, echinoderms, worm tubes, sponge spicules, ostracodes, monoplacopharia, brachiopods and fish.
2. Skeletons are mainly in sand and fine sand with minor in very fine sand fractions. Fauna types vary with grain-size: bryozoans are in the sand to gravel-size fractions, foraminifera are in the fine sand fractions, whereas molluscan are mainly in the gravel fractions. Echinoderms and algae are in the sand fraction, whereas sponge spicules occur in the fine to very fine sand-size fraction. ,
3. Bulk Mg values of the 44 samples studied indicate high-Mg calcites. Mg, Sr, and Na values are positively related to bryozoan content. Higher Sr and Na values of Tasmanian bryozoans relative to tropical counterparts indicate higher rate of bryozoan skeletal formation in temperate waters than in tropical waters. Mn and Fe contents are incorporated into calcite in a dysaerobic marine environment.
4. Tasmanian temperate faunal assemblages differ from tropical chlorozoan assemblages due to variation of seawater temperatures. Normal salinities and high nutrient content allow luxuriant growth of fauna, particularly bryozoans. After their death, bryozoans break down into fragments and these are later sorted into gravel to sand grains by strong currents that winnow away fines. Lack of mineralogical and geochemical evidence of meteoric diagenesis and positive correlation of Mg, Sr and Na with modern high-Mg calcite bryozoans indicate continuous marine sedimentation during Holocene.

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