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Subsidence at the Cape Roberts Project (CRP) Drillsites from Backstripping Techniques, Victoria Land Basin, Antarctica

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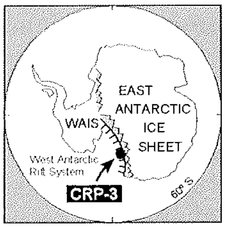
Abstract - The tectonic subsidence of the western margin of the Victoria Land basin has been estimated from the physical properties and ages of the sediments in the Cape Roberts Project drillcores 2/2A and 3, using backstripping techniques. The analysis indicates a total tectonic subsidence of about 660 m at this location between 34 Ma and the present. Two main trends are defined, i) about 230 m/m.y. from 34 Ma to 32.5 Ma, and ii) about 23 m/m.y. from 32.5 Ma to 21 Ma. Since 21 Ma, the subsidence is not well constrained. Extrapolation indicates a very low subsidence rate, but uplift within this period may have greatly affected the estimate. Seismic reflection data further east, towards the centre of the basin, indicates several episodes of extension and associated high subsidence rates since 21 Ma.



INTRODUCTION

An initial assessment of the geohistory of the Victoria Land basin (VLB) at the CRP drillsites was presented in the Initial Report of the CRP-3 drill core (Cape Roberts Science Team (CRST) 2000, Fig. 7.6, p. 197). It was based on ages and thickness from all the three drillholes, with the core added to each other and assumed to be under CRP1 site with allowance made for inferred overlap or gaps. The diagram shows the total subsidence of the basement of the VLB through time. The total subsidence is caused by tectonic driving forces and sediment load. We apply the backstripping technique of Steckler & Watts (1978) to the CRP2 and CRP3 drillcores separately in order to remove the sediment load effects from the total subsidence and then obtain the tectonic contribution through time at each location. Our models for CRP2 and CRP3, when put together, show how the tectonic subsidence rate has changed throughout time at these sites. Simple subsidence is assumed, and no allowances made for any uplift events. The results will, therefore, give minimum subsidence and subsidence rates.

METHODS

The backstripping technique comprises: removing each of the sedimentary units, starting with the youngest one and progressively decompacting the lower units (decompaction); correcting the depth of each unit for the isostatic uplift after having removed the upper sediment and water load (isostatic compensation); correcting the water depth taking in consideration the depth at the time of deposition, that determines its position relative to a datum (such as present-day sea level) correcting for long term, global eustatic sea level changes.

For the modelling at the CRP2 and CRP3 drillsites, the present porosity data from the drillcore has been used (CRST, 1999 and CRST, 2000), and local isostatic compensation assumed.

The CRP-2 and CRP-3 cores have been subdivided into 4 and 5 units respectively, bounded by those unconformities/horizons recognised to be most significant by other studies on the CRP cores. Tables 1 and 2 list the unconformities used in this study for CRP-2 and CRP-3 respectively.

The thin breccia and conglomerate deposited above the basement (Beacon Supergroup quartzose sandstone) (between 823.11 m and 790 mbsf) at CRP-3 is assumed to represent the lowermost rigid base in our modelling for the CRP-3 drillsite. The curve on the right of the diagram in figure 1 shows the tectonic subsidence of this horizon throughout time and it is reasonably representative of the tectonic subsidence of the geologic basement.

CRP-2 did not reach the same breccia and conglomerate layer or the Beacon basement, and the bottom of the drillcore sampled glacimarine mudstone and sandstone. The seismic section across the two drillsites (Fig. 2) does not allow extrapolation of the depth of the breccia layer from CRP-3 to the CRP-2.

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Tab. 1 - CRP-2 horizons used for this work.

Age* (Ma)	Present depth (meters bsf)	Paleo-water depth* (meters bsl)
21	130	10
24.1	307	10
27- 29.5	443	10
30	bottom	10

Notes: *From the CRP-2 initial report; bsf beneath seafloor; bsl beneath sealevel.

Tab. 2 - CRP-3 horizons used for this work.

Age* (Ma)	Present depth (meters bsf)	Paleo-water depth* (meters bsl)
31.5	75	50-120
32.5	95.48	50-120
33	225	50-120
33-34	580	0-50
34	790	0

Notes: *From the CRP-3 initial report and from Florindo et al. (this volume) and Hannah et al. (this volume); bsf beneath seafloor; bsl beneath sea level.

Therefore, the absolute values of the two curves in figure 1 cannot be used to construct one combined curve, because they represent the theoretical palaeo-depths throughout time, resulting from tectonic vertical movement, of two different horizons within the sedimentary column. These horizons are the breccia and conglomerate layer at the bottom of the CRP-3 core and the glacimarine mudstone and sandstone at the bottom core at CRP-2. However, these two curves may be used to see the trend of the tectonic subsidence that has occurred:

- from the time of deposition of marine sediments above the breccia layer (34 Ma) to the time of deposition of sediments at the top of the CRP-3 site (31 Ma), and
- from the time of deposition of sediments at the bottom of CRP-2 (30 Ma) to the time of deposition of sediments at the top of CRP-2 (*ca.* 21 Ma).

The dashed line in figure 1 represents the tectonic subsidence of the basement at CRP-3 site between 31 Ma and present, inferred from the trend obtained at CRP-2 (from 30 to 21 Ma) and the calculated depth of basement (660 m) caused by the tectonic subsidence at the present time at the CRP-3 site. The palaeo-depth information obtained from bio-stratigraphic studies on the CRP-3 core have a wide range of uncertainty, about 50-120 m. This would affect the computation of the absolute values of the curve in figure 1, but not significantly its general trend. It must be also noted that the age of the unconformity at 443 mbsf in the CRP-2 core is not well constrained and probably lies within the range from 27 to 29.5 Ma. The age selected within this range would affect the shape and the gradient of the curve in figure 1 that illustrates the tectonic subsidence at CRP-2.

RESULTS AND DISCUSSION

The results of backstripping analysis of the core at the drill sites indicate two main trends in tectonic subsidence. A fast subsidence occurred from about 34 Ma to 32.5 Ma, the younger time corresponding to. 95.48 mbsf at CRP-3 site. A slower period of subsidence is observed from 32.5 Ma to 21 Ma (Fig. 1). The depth of 95.48 mbsf at CRP-3 corresponds to the base of sequence 2. The sedimentary log in the CRP3 initial result volume shows that the base of sequence 2 is represented by a lithologic change from a coarse unit to fine sediments.

Moreover there is a significant increase in the number of the stratigraphic sequences, erosion events, and diamictite and conglomerate layers below the depth of 115-120 m (CRST 2000, Fig. 3.3). In addition, metamorphic rocks are absent above this depth while they are common below it (CRST 2000, Fig. 4.2), and three large-scale fault zones are observed below this depth (CRST 2000, Fig. 2.14). A detailed correlation between seismic and lithologic boundaries is limited by the resolution of the seismic data (*ca.* 20 m, see Henrys et al. this volume). However the synthetic log constructed by Henrys et al. (this volume) suggests that the depth of 95.48 m bsf at CRP-3 correlates with the reflector "p", originated by a strong acoustic reflection at the boundary between a coarse layers package (at least 20 m thick) overlying by fine sediments. A change in the subsidence rate from fast to slow, that occurred at about 95.48 m bsf, is consistent with the geometric

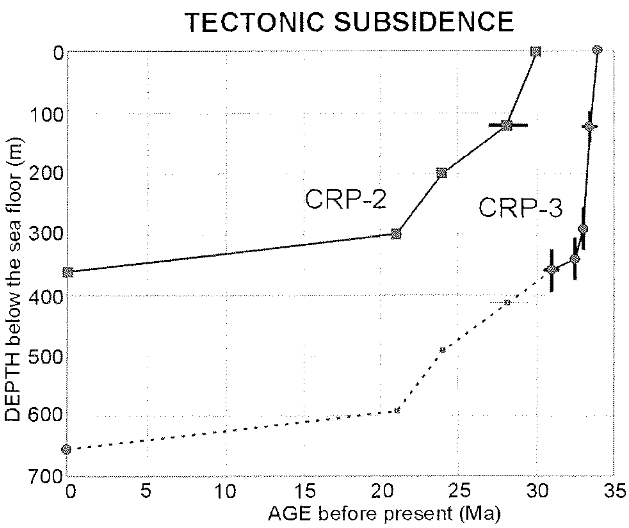

Fig. 1 - Tectonic subsidence curves obtained using backstripping technique at the CRP-2 (squares) and the CRP-3 (circles) drillsites. The dashed curve represents the extrapolated tectonic subsidence of the basement at CRP-3 site between 31 Ma and present. This curve is inferred from the trend at CRP-2 (from 30 to 21 Ma) and the depth of the basement caused by the tectonics at present time at the CRP-3 site. The error bars indicate the range of the uncertainties in the palaeo-depth information and age.

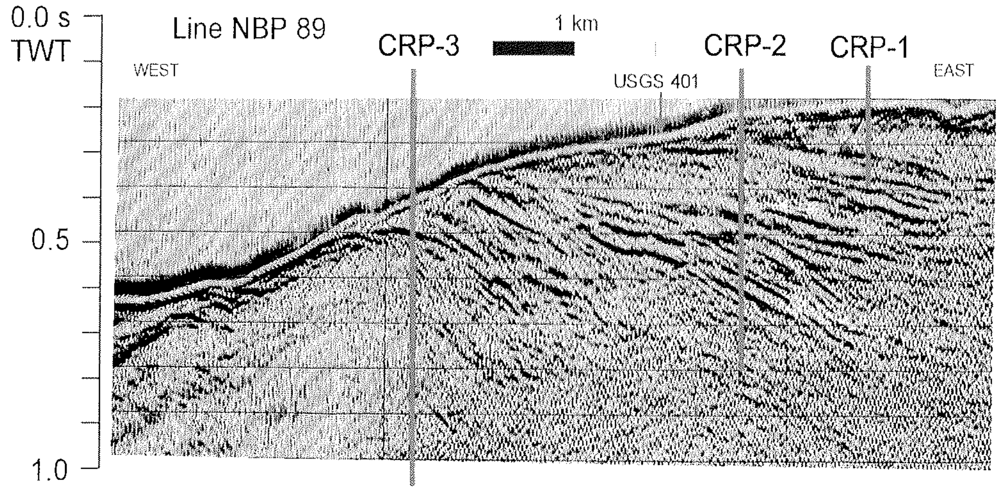

Fig. 2a - Seismic section of multichannel line NBP89 across the drillsites.

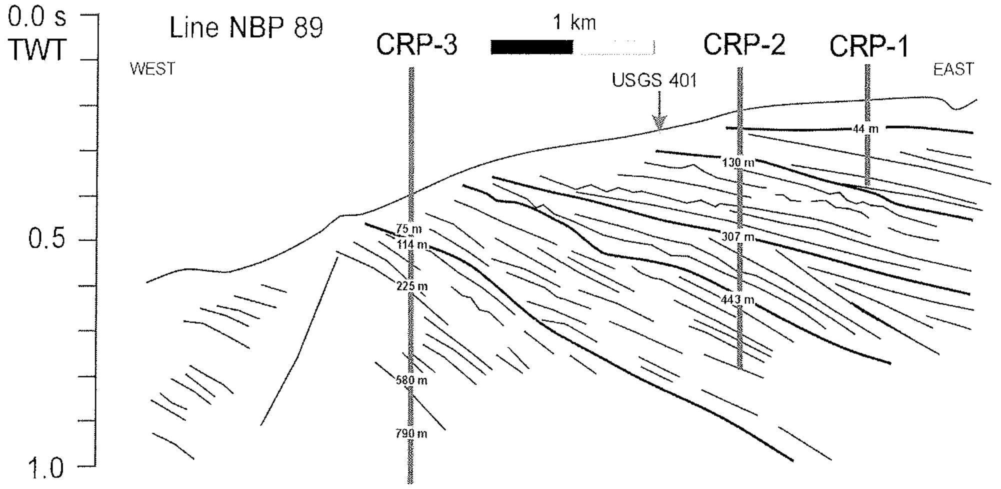

Fig. 2b - Line drawing of multichannel seismic line NBP89 across the drillsites.

pattern of the seismic reflectors observed on the profile across the drillsite (Fig. 2). On this seismic line the sedimentary strata lying below the horizon "p" that correlates with the 95.48 m bsf at CRP-3 drill site dip toward east with high angle. This same horizon is onlapped by reflectors that dip toward east with a gentler angle.

No significant change in the tectonic subsidence rate is observed at the time (*ca.* 34 My) of the change in depositional style in the CRP-3 core recorded by the sedimentary facies at the depth of 580 mbsf. In the Initial Report (CRST, 2000) the depth of basin deposition was interpreted to become shallower for the core sediments above about 580 m bsf, suggesting a decline in the rate of subsidence that allowed the basin to fill to a higher level. The penetration in depth of the seismic profile across the drillsite is not sufficient to distinguish any relevant acoustic and strata geometry change at this depth.

A major erosion event was recorded at depth of 443 m bsf at the CRP-2 site although the age of the hiatus is not well constrained (27-29.5 Ma; CRST, 1999). Across the 443 mbsf unconformity, a change from thick to thinner sedimentary cycles was also observed and it was previously inferred to represent a decreasing in the subsidence rate (CRST 1999). We do not observe any significant change in the tectonic subsidence rate during the time of formation of the unconformity across 443 mbsf. The subsidence trend during this time is similar to that between 32 and 31 Ma at the CRP-3 site (Fig. 1), even considering the uncertain chronology for the hiatus at 443 mbsf. The seismic line NBP 89 (Fig. 2) shows that the strata above and below the unconformity at 443 mbsf dip toward east with similar angle, suggesting to us that no large variation in the tectonic subsidence rate occurred during the deposition of these strata. The reflector that correlates with the unconformity at 443 mbsf truncates the underlying strata and is a downlap surface and the sediments below the unconformity are generally finer than those above the unconformity (CRST, 1999). This suggests that the

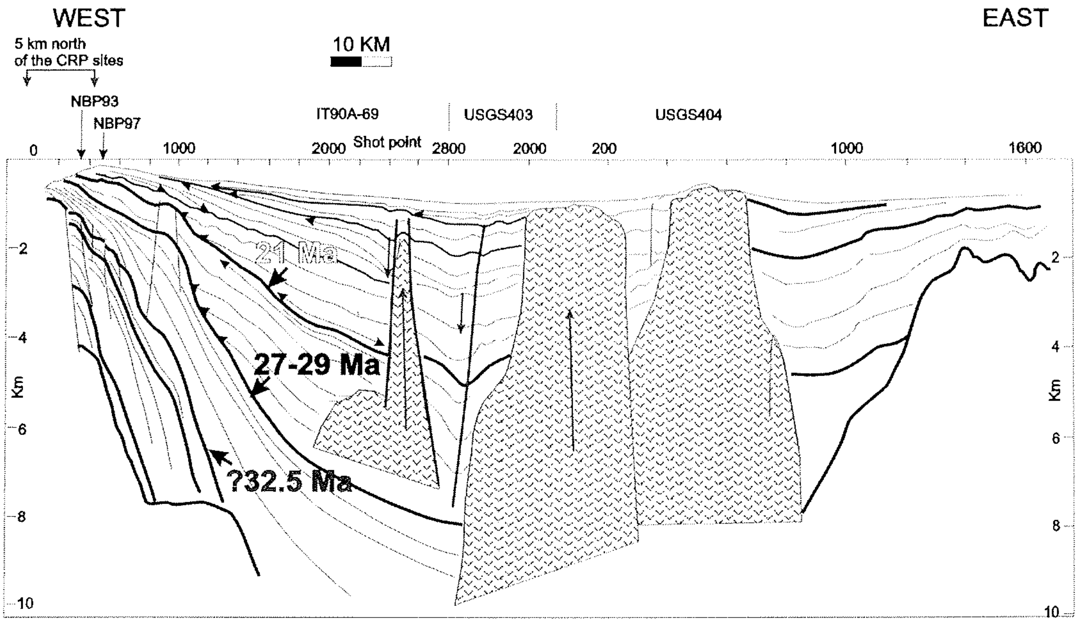

Fig. 3 - Line drawing of a composite multichannel seismic section made by IT69, US 403 and US 404 across the VLB about 5 km north of the CRP drillsites.

change from thick to thinner cycles, previously inferred to represent a decreasing in the subsidence rate (CRST, 1999), could be explained with sea level change and/or sediment supply rather than with tectonics rate change.

Another major erosion event was recorded at depth of 307 mbsf at the CRP-2 site. The age of the end of this erosion event is given by the age of the sediments lying above it, that is 24.1 Ma, although the hiatus span is not well constrained because the age of sediment below the unconformity is still uncertain (24.1-29 Ma).

The seismic line across the drillsite (Fig. 2) shows that the unconformity at 307 m bsf at the CRP-2 site correlates with a reflector that sharply truncates eastward inclined strata with high angle. East of the CRP-2 drill site, those inclined strata are onlapped by younger strata that dip toward east at a smaller angle. This geometric configuration suggests that the time span of the unconformity recorded at 307 m bsf could be relatively long, considering that erosion was taking place at the drillsite while deposition was taking place to the east of the drillsite. Until the age of the sediments below this erosion unconformity is known, we cannot estimate the amount of erosion that occurred and the actual time span of such an unconformity. The backstripping of the CRP-2 core shows no significant deviation in the overall tectonic subsidence rate from the general trend observed since 32.5 Ma.

Extrapolation to the present indicates a much slower subsidence rate at the CRP drillsites since the formation of the unconformity at 21 Ma. This may reflect the uplift and erosion after subsidence of this region since that time (Davey & Henrys 1999). Seismic sections across the Victoria Land Basin (Cooper et. al. 1987, De Santis et. al. 1994) show that a significant amount of the sediments deposited into the basin is younger than 21 Ma (Fig. 3). These sediments are contained within several packages of strata that dip toward east with relatively high angle, that are bound by truncation unconformities, and onlapped by more recent strata. The eastern margin of the basin is intruded by magmatic bodies of relatively young age, clearly folding up the sedimentary strata and the present sea floor (Fig. 3). This would suggest that several episodes of fast extensional tectonics and associated subsidence also occurred in and after Miocene time, and gradually migrated toward the eastern sector of the VLB (De Santis et al., 1994). The result of such a tectonic model would be the overall subsidence slow down in the westernmost sector of the VLB, around the CRP site area. Further work still needs to be done to estimate the amount of stretching and the tectonic subsidence that occurred during this phase.

CONCLUSION

Tectonic subsidence, at rates of about 230 m/m.y, affected the area around the CRP drillsites from about 34 Ma to about 32.5 Ma. After that time, subsidence rates dropped to about 23 m/m.y. until about 20 Ma. The age and the calculated fast rates of the tectonic subsidence affecting the western Ross sea is consistent with studies made in the Central and Eastern Ross Sea (De Santis et al., 2000) that suggest an Oligocene age of the basin opening phase in those regions. Since 20 Ma, extrapolation of the tectonic subsidence curves indicates a period of very low subsidence. Seismic reflection data across the VLB indicates that extensional tectonics was diachronous within the VLB and it was progressively younger toward east, as previously observed by De Santis et al. (1994), and possibly toward south. We believe that the apparent major slow down of the overall subsidence rate after about 20 Ma may be the result of subsequent uplift of the region and migration of the extensional tectonics toward east and south.

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