

BASEMENT UPLIFT AND BASIN SUBSIDENCE IN
CENTRAL AUSTRALIA

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STATEMENT

The studies described in this thesis were undertaken while I was a full-time research scholar in the Research School of Earth Sciences, Australian National University, during the period June 1983 to September 1987.

Except where mentioned in the text or in the acknowledgements, the research described in this thesis is my own.

This thesis has never been submitted to another university or similar institution.



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	Basin Type	Maximum Basin Width (km)	Max subsidence (km)	Depocentre migration and position	Max shoulder uplift (km)	Ratio of subsidence to uplift	Change in rate of subsidence	Timing	References
COMPRESSIONAL	Foreland	200-400+	10+	Ahead of thrust; basin partly re-moved by iso-static rebound	Up to 10+; 1-2 in geological examples	0.3-0.1 (narrow load) 1.2-1.6 0.8-1.8	Progressive increase	Episodic, rapid subsidence follows thrust advance, lasting 10 to 50 Ma+	Jordan, 1981; Beaumont, 1981
	Tilted Fault Block	100+	10+	Minimal, along-side reverse fault	1-10+	0.65-0.95	Erratic, episodic	Rapid, possibly episodic	Lloyd, 1986; Beaumont, (per comm.)
	Visco-elastic	130-	10+	Towards basement	< 10	0.3-0.90	Progressive increase	Long-lived i.e. 200 Ma	Lambeck, 1983
	Thermal	Indefinite	4 ⁺	Minimal, over region of thermal expansion	up to 1.0; normally 300-500m	> 2.0	Exponential decay	Up to 150 Ma+	Sleep, 1971; Sleep & Shell, 1976; Cochran, 1983
EXTENSIONAL	Stretching	Initially 30-40 Finally 200-300	6.2	Minor	Minimal	2.5-20, typically 6-10	Rapid then exponential decay	Rift phase 5-25 Ma, rarely 50Ma; sag phase lasts up to 180 Ma	McKenzie, 1978 Le Pichon & Sibuet, 1981 Cochran 1983.
	Dynamic Extension/ Mantle Plume	Unspecified 500±?	5+	Centred over region of dynamic uplift, no migration	Minimal	0-20	Rapid decay on plume removal, then exponential	Uplift lasting 5-50Ma+ sag phase lasting 150Ma+	Houseman & England, 1986.

CHAPTER 2

CRUSTAL STRUCTURE IN CENTRAL AUSTRALLIA

TABLE: 2-1 Averaged Surface Rock Densities of Basement
Rocks and Estimated Compressional Seismic Velocities

BLOCK	ROCK TYPES (%)	WET DENSITY gcm ⁻³ (s.d.)	NO OF SAMPLES	BULK DENSITY gcm ⁻³	ESTIMATED SEISMIC VELOCITY kms ⁻¹ *2
1	Amadeus Basin sequence			2.64	4.5 *3
	Ngalia Basin sequence				5.0+ *3
2	Granitic gneiss, granitoid (40%)	2.65 (0.04)	20		
	Quartzofeldspathic gneiss (20%)	2.71 (0.04)	6	2.71	6.5
	Migmatitic biotite gneiss (35%)	2.80	1		
	Schist, amphibolite (5%)	2.66	2		
3	Granitoid (80%)	2.67 (0.03)	5		
	Quartzofeldspathic gneiss (15%)	2.71 (0.04)	6	2.68	6.4
	Biotite gneiss, schist (5%)	2.70	2		
4	Quartzofeldspathic gneiss (55%)	2.70 *1			
	Migmatitic biotite gneiss (35%)	2.71	3	2.72	6.5
	Mafic granulite (5%)	3.05	3		
	Pelitic gneiss (5%)	2.71	2		
5	Potassic mafic granulite (50%)	2.86	6		6.7
	Mafic granulite (10%)	3.00	1	2.81	
	Felsic gneiss and granulite (25%)	2.67	4		
	Granodiorite gneiss (14%)	2.72	14		
	Metasediment (1%)	2.73	1		
6	Augen gneiss, granitoid (90%)	2.72 (0.07)	24	2.73	6.5
	Mylonitised gneiss (10%)	2.71	8		
7	Potassic mafic granulite (65%)	2.96 (0.09)	32		
	Mafic granulite (20%)	3.05 (0.06)	47		
	Felsic granulite & gneiss	2.77 (0.10)	11	2.95	7.0
	Mafic orthopyroxene-bearing granitoid (1%)	2.99	4		
	Pelitic gneiss (1%)	2.81	1		

TABLE: 2-1 (Cont.)

BLOCK	ROCK TYPES (%)	WET DENSITY gcm ⁻³	NO OF SAMPLES	BULK DENSITY gcm ⁻³	ESTIMATED SEISMIC VELOCITY Kms ⁻¹ 2*
8	Pelitic gneiss (45%)	2.73	2		
	Quartzofeldspathic gneiss (35%)	2.71*2		2.73	6.5
	Mafic granulite (10%)	2.85	2		
	Granitoid (10%)	2.72	2		
9	Granitoid (70%)	2.72	2	2.72	6.5
	Metasediment (30%)	2.73	1		
10	Metaquartzite (70%)	2.70	2	2.71	6.5
	Metasediment (30%)	2.73			
11	Mafic granulite (95%)	3.05			
	Potassic mafic granulite (2%)	2.96	50	3.04	7.2
	Granitic gneiss (2%)	2.72			
	Anorthositic gneiss (1%)	2.94			

* 1. Estimate based on ground scintillometer traverses

2. $V_p = 0.31 + 2.27p$ (Christian & Fountain, 1975)

3. Froelich & Krieg (1969); Wells & Moss (1983)

CHAPTER 3

STRUCTURE AND UPLIFT HISTORY OF THE BASEMENT

Table 3-1. Summary of deformation phases in the granulite facies and amphibolite facies terranes.

GRANULITE TERRANE (NTH)	AMPHIBOLITE TERRANE (STH)
$D_1^N, F_1^N, S_1^N, L_1^N$ Structural elements formed before granulite metamorphism	
Granitoid Emplacement	
$D_2^N, F_2^N, S_2^N, L_2^N$ At or preceding peak granulite metamorphism and migmatisation	
Dolerite Dykes emplaced and metamorphosed at granulite grade	
	$D_1^S, F_1^S, S_1^S, L_1^S$ Amphibolite metam.
	$D_2^S, F_2^S, S_2^S, L_2^S$ Amphibolite metam.
$D_3^N, F_3^N, S_3^N, L_3^N, Sm_3$ Type 1 high-grade mylonite	
$D_4^N, F_4^N, S_4^N, L_4^N$ Mild, open folding accompanying extensive recrystallisation	$D_3^S, F_3^S, S_3^S, L_3^S$ Extensive migmatisation
Migmatisation and pegmatite	Anatectic granitoids
Dolerites of Stuart Dyke Swarm emplaced	
D_5^N, F_5^N, Sm_5, Lm_5 Type 2 low-grade mylonite	D_4^S, F_4^S, Sm_4, Lm_4 Greenschist mylonites

Table 3-2. Deformational and Metamorphic Phases in the Granulite Terrane.

DEFM	FOLDING	METAMORPHISM	MIGMATISATION	AXIAL-PLANE STRUCTURES	REGIONAL STRAIN
D ₁ ^N	Rootless, intrafolial reclined	Early granulite	Layer-parallel leucosomes	Gneissic layering, granoblastic microstructures	S fabrics weak to absent, S ₀ transposed
GRANITOID EMPLACEMENT					
D ₂ ^N	Isoclinal, reclined, cylindrical	Late-stage granulite	Mobilisate, with opx cross-cuts S ₂	Gneissic layering to domainal S, mobilisate	L-S and L fabrics, S weak
REGIONAL MIGMATISATION, RECRYSTALLISATION, MINOR GRANITOID EMPLACEMENT					
D ₃ ^N	Mesoscopic, uncommon	Retrograde, amphibolite	Absent	Penetrative schistosity	Local zones of shearing
D ₄ ^N	upright, open	amphibolite in Sth	Syn-migmatite in Sth	Incipient crenulation cleav.	Low strain Minor shortening
LATE MIGMATITE AND PEGAMATITE EMPLACEMENT					
D ₅ ^N	Early: tight, reclined Late: open, upright, E-W	Upper greenschist to lower amphibolite grade	Absent	Early folds: mylonitic foliation	Extreme crustal shortening

Table 3-3. Deformational Phases in the Amphibolite Terrane

	FOLDING	METAMORPHISM	MIGMATISATION	AXIAL-PLANE STRUCTURES	REGIONAL STRAIN
D1	Tight, reclined, mesoscopic	Amphibolite	Absent	Micaceous schistosity	Possible thrusting (Teyssier et al, 1988)
D2	Isoclinal, reclined to recumbent	Amphibolite, pressure up late in D2?	Absent	Micaceous schistosity	Northerly elongation, shortening due to thrusting
D3	Open to tight, steep in N, gentle in S	Amphibolite	Extensive	Steep, weak S3 crenulations, sub-parallel mobilisate	Mild, N-S shortening, F3 Sth verging in SE
D4	Early: isoclinal, reclined Late: upright	Greenschist	Absent	Fine biotite foliation, micro-shearing, quartz veins	N to S sense of shear in mylonite zones, crustal shortening

TABLE 3-4 Outline of features distinguishing Type 1 and Type 2 mylonites

FEATURE	TYPE 1	TYPE 2
SCHISTOSITY	Alignment of medium-grained biotite; slightly gneissic	Alignment of very fine grained, inhomogeneous biotite
MATRIX TEXTURE	Granuloblastic	Both strained and polygonal grains
QUARTZ DEFORMATION	Recrystallised, ribbon-shaped aggregates	Deformation bands, ribbons, polygonal grains: i.e. dynamic recrystallisation
FELDSPAR DEFORMATION	Megacrysts recrystallised at margins or completely recrystallised	Augen fractured, minor recrystallisation at ends in most deformed rocks
GRAIN SIZE	5mm to 0.01 mm and greater	0.02mm to 0.001 and less
NATURE OF STRAIN	L, L-S Tectonites; rapid variation in intensity common	L-S, S Tectonites
METAMORPHIC GRADE	Upper amphibolite; blue-green hornblende (hastingsite?), new garnet (andradite), new biotite	Greenschist to lower amphibolite assemblages; white mica, biotite, epidote
RELATIONS	Folded, cut by pegmatite, migmatite	Rarely folded, deforms pegmatite and migmatite

Table 3-5. Main Features of Type I Mylonites, and D1 and D2 Deformed rocks in the granulite terrane

TYPE	QUARTZ	BIOTITE	HORNBLende	PYROXENE	GARNET	FELDSPAR
D1	Granular	Rare	Granular	Granular	Granular	Granular
GRANITOID EMPLACEMENT						
D2	Elongate, irregular grains	Commonly grey-Olive-brown, coarse, green, weak foliation granular		Granular	Poikiloblastic, opaque cores in some	Partly recrystallised
MIGMATITE EVENT, DOLERITE INTRUSION, THEN END OF GRANULITE METAMORPHISM						
IA (1)	Elongate, platy	Foxy brown, coarse grained	Green, elongate	Opx with intergrown bio., qtz	Poikiloblastic hbde, bio., qtz inclns	Elongate, some partly recrystallised
IA (2)	As above, partly recrystallised	As above	Emerald-green	Relict opx in some	Deformed if present, plus new	Partly recrystallised
IB	Partly recrystallised quartz ribbons	Grey-brown, yellow-brown, bimodal	Deformed green, some bluish tints	Rare relict opx	Minor, deformed	Recrystallised incipient fractures
IC	As above, grain growth	Green-brown, yellow, bimodal	As above	Absent	Old deformed, plus new idioblastic	Recrystallised along fractures
ID	Polygonal, annealed	As above fine late bio., musc., epid.	As above	Absent	Grain growth, D5 overprint	

Table 3-6 Main features of mylonitic rocks in Type 2 deformed zones.

TABLE 3-6 MAIN FEATURES OF MYLONITIC ROCKS IN TYPE II DEFORMED ZONES

FEATURE	TYPE 1A MYLONITIC ROCK	TYPE B PHILONITIC PROTOMYLONITE	TYPE C PHILONITIC MYLONITE	TYPE D ULTRAMYLONITE	TYPE E PSEUDOTACHYLITE
% Mylonitic matrix	0 - 10	10 - 50	50 - 90	90 - 100	-
Relationships	Marginal to protomylonite	Deforms pegmatite dykes, sigmoidite, E-W dolerite dykes	Grades locally into protomylonite and ultramylonite.	Grades locally into mylonite and pseudotachylite; also occurs independently	Accompanies brecciation and brittle failure of ultramylonite, also associated with brittle failure of gneiss/granulite overlying ultramylonite zones.
Distribution and macroscopic geometry	Marginal to protomylonite	Forms network of anastomosing and banded E-W zones at granulite/ amphibolite terrain boundary	Overlies protomylonite zones and also forms narrow zones in partly retrogressed granulite/granulite terrain	Overlies mylonite and also forms narrow zones in partly retrogressed granulite/granulite terrain.	Occurs in Mt Ziel and Mt Baughlin massifs overlying and within ultramylonite zones
Metamorphic grade		Epidote becomes conspicuous, new white mica appears; dynamic recrystallisation of quartz suggests temperatures above 300°C (Kerrick et al., 1977)	New white mica and biotite increase in abundance. Above brittle ductile transition for feldspar (cf. Voll, 1976; Tullis & Yund, 1980), i.e. possibly as high as 450°C.		LOWER AMPHIBOLITE/UPPER GREENSCHIST FACIES. Assemblage includes biotite, white mica, epidote
Metasomatism/ Chemical Features	Epidote formed quartz veins e.g. 1187			Oxidised in places with formation of magnetite; compositional laminations	Abundant disseminated Ti/Fe oxide
Megacrystic Susceptibility ($k \times 10^{-6}$ SI units)	100	300	250	20 000	20 000
Radiometric response (c/s)	80	60	80	-	-
Lamination	Layering/schistosity intersection	Fine, marked stretching lamination where present	Stretching lamination typically down-dip	Stretching lamination commonly weak to absent	
Foliation	Inhomogeneously distributed schistosity outlined by very fine biotite	Anastomosing	Commonly planar	Compositional laminations typical	
Feldspar morphology/deformation	Some fractured grains	Globular, elliptical, or irregularly shaped grains; some fractured grains	Minor recrystallisation of augen tails	Minor recrystallisation of augen tails	
Quartz morphology/deformation	Unchlored extinction, deformation bands, some finely recrystallised grains associated with very fine biotite outlining foliation	Quartz typically strained, some ribbon shaped grains, minor dynamic recrystallisation	Polygonised quartz typical	Some contain "dipy" ribbon shaped grains; some polygonised quartz.	

Table 3-7 Summary of metamorphic assemblages in the granulite terrane.

Table: 3-7 Summary of Metamorphic Assemblages
in the granulite terrain

	Mt. Hay massif	Mt. Chapple massif	Mt. Ziel & Mt. Heughlin Redbank Hill massifs
Mafic granulite	hbd-opx-cpx-plg, opx-cpx-plg + qtz,	hbd-opx-cpx-plg, + bio + gnt + ilm, cpx-opx-plg	opx-cpx-hbd-plg + qnt, bio-cpx-hbd-plg
"Intermediate" granulite	hbd-opx-plg-qtz, opx-ksp-plg-qtz,	hbd-opx-cpx-plg, -ksp-qtz + qnt + bio,	qnt-opx-cpx-hbd -bio-ksp-plg-qtz, qnt-hbd-bio-plg -ksp-qtz
Felsic granulite and gneiss		opx-ksp-plg-qtz, gnt-hbd-opx-cpx- ksp-qtz + plg + bio, gnt-hbd-opx-plg-qtz, gnt-bio-ksp-plg- qtz (W margin), hbd-bio-ksp- plg-qtz	gnt-hbd-bio-plg ksp-qtz

Table 3-8 **Summary of PT determination.**

TABLE: 3-8 Summary of PT Determinations: see Figure 2-7 for location of sites

SITE	DEFM *(SEE BELOW)	SPECIMEN NO.	TEMPERATURE ((R) SEE BELOW)	METHOD (SEE BELOW)	PRESSURE	METHOD (SEE BELOW)	ROCK TYPE
1	D ₂	H601	750	W	9.8	E	mafic granulite: opx-cpx-qtz-hbl - bio-plg-ilm-ap
2	D ₂ ; D ₃	H602	760 560-680 (R)	H F	7.0	P	augen gneiss: gnt-ksp-qtz-hbl-plg- opx
3	D ₁	H618A	750	W	8.6	E	mafic granulite: opx-cpx-plg-qtz- hbl-qtz
4	D ₂ ; D ₃	H619	700+ 632 (R)	\$(see below) F	8.2+	B	pelitic gneiss: qtz-gnt-sm-plg- ksp-bio-ilm-ru
5	*	G8B (H345)	590	F	4.0	W	pelitic gneiss: qtz-plg-ksp-bio- gnt-sm-zir, opq
6	*	G8C (H346)	650	F	4.7	W	pelitic gneiss: qtz-ksp-plg-sm- bio-zir-opq
7	D ₃ (1B)	N11A (H358)	700+ 600 (R)	F	-	-	quartz plagioclase gneiss: qtz- plg-gnt-bio-hbl-mt
8	D ₂	D4 (H338)	700	G	7.0	P	potassic mafic granulite: gar- opx-plg-qtz-ksp-hbl-bio-ilm
9	D ₂	H618B	700+	H	8.0	B	mafic granulite: gnt-opx-hbl-plg- qtz-bio-opq-zir
10	D ₂	1162A	715	H	8.5	B	mafic granulite: gnt-opx-hbl-plg- qtz-bio-cpx-ilm-mt
11	D ₂	1356	700	F	-	-	mafic potassic granulite: gnt- hbl-bio-plg-qtz-ksp-mt

TABLE: 3-8 (Continued)

SITE	DEFM *(SEE BELOW)	SPECIMEN NO.	TEMPERATURE (°SEE BELOW)	METHOD (SEE BELOW)	PRESSURE	METHOD (SEE BELOW)	ROCK TYPE
12	D ₂	H623	710 565(R)	G F	7.0	F	felsic (aluminous) granulite: gnt-opx-ksp-plg-qtz-bio-mt
13	D ₂ ; D ₃ (1A)	1352	700+	F	-	-	augen gneiss: gnt-hbl-bio- ksp-plg-qtz-sp-opq
			640(R)				
14	D ₂	1350	700	EG	8.5	E	potassic mafic granulite: gnt-hbl-opx-cpx-qtz-plg-ksp- mt-ilrn-zir
15	D ₁	1132	790	W	9.1	E	metagabbro: opx-cpx-qtz- plg-bio-hbl-opq
16	D ₃ (1D)	1122	630	F	-	-	mylonite: gnt-bio-hbl-plg- qtz-ksp-opq
17	D ₂	1163	770 700	W H,G	9.5 9.5	W B	mafic granulite: gnt-hbl-bio- opx-cpx-plg-qtz-mt
18	D ₁	MH2A	720 720	EG G	9.4 9.5	B B	mafic granulite: gnt-opx- cpx-plg-qtz-opq
19	D ₂	MH1C	720	EG	9.0	B,W	mafic granulite: gnt-hbl-cpx- opx-plg-qtz-ilrn
20	D ₂	1305	730 740	EG W	9.0 8.5	B E	potassic mafic granulite: gnt-hbl-opx-cpx-plg-ksp-bio- qtz-ilrn-mt-zir
21	D ₂	MH3B	740	G	9.0	E	mafic granulite: gnt-hbl-plg- cpx-qtz-bio-mt-ilrn
23	*						

TABLE: 3-8 (Continued)

* Part of Amphibolite Terrain	
R	Based on late, retrograde garnet
\$	For 5m to be stable with ilm, + Fe - ant requires T = 700°C(Ca) and a _{H2O} = 1.0(Ca)
Geothermometry methods:	
EG	Ellis & Green (1979) ± 50°C
F	Ferry & Spear (1978) ± 50°C
G	Harley & Green (1982) ± 25°C
H	Harley (1981) ± 50°C
W	Wood & Banno (1973) ± 60°C reduced empirically by 60°C; formulation after Davis & Boyd (1966)
Geobarometry methods:	
B	Bohlen et al (1983) ± 0.5kb
E	Ellis (1980) ± 1kb or more
P	Perkins & Newton (1981) ± 1.5kb
W	Phillips & Wall (1-81)
Mineral Abbreviations:	
ap - apatite, bio - biotite, cpx - clinopyroxene, chl - chlorite, ep - epidote, gnt - garnet, hbl - hornblende, ilm - ilmenite, ksp - alkali feldspar, ms - muscovite, mt - magnetite, opq - Ti/Fe oxide, opx - orthopyroxene, plg - plagioclase, qtz - quartz, ru - rutile, sm - sillimanite, zir - zircon.	

Table 3-9 **Summary descriptions of samples.**

TABLE: 3-9 Summary description of samples and sample locations

SITE	SAMPLE NO. 8409-	LOCATION	ROCK TYPE	MINERAL ASSEMBLAGE	MYLONITE CLASSIFICATION
D	1641	W Flank Redbank Hill massif	mylonitic gneiss	Qtz-plg-ksp-bio-hbl-gnt-opq-ap-zir	Type 1B
W	1644	SW Flank Redbank Hill massif	mylonite	Qtz-plg-ksp-bio-hbl-gnt-opq	Type 1C
R	1676	W Flank Mt Heughlin	ultra-mylonite	Qtz-ksp-plg-bio-ms-ep-mt	Type 2
	1677	as above	mylonitic gneiss	Qtz-ksp-plg-bio-gnt-(opq-zir)	Type 1A(2)
K	1681	2km N Mt Heughlin	mylonitic gneiss	Qtz-plg-ksp-bio-opx-hbl-opq	Type 1A(2)
H	1686	6km E Mt Ziel	mylonitic gneiss	Qtz-plg-ksp-bio-hbl-gnt-opx (zir-ap)	Type 1A(2)

Mineral abbreviations: ap - apatite, bio - biotite, ep - epidote, gnt - garnet, hbl - hornblende, ksp - alkali feldspar, ms - muscovite, mt - magnetite, plg - plagioclase, qtz - quartz, zir - zircon.

SAMPLE LOCATIONS:

SITE	LATITUDE	LONGITUDE
D	23° 25.55'	132° 44.62'
W	23° 25.67'	132° 45.58'
R	23° 20.35'	132° 12.12'
K	23° 19.82'	132° 14.45'
H	23° 24.10'	132° 26.45'

Table 3-10 Summary of Rb-Sr isochron information.

TABLE: 3-10 SUMMARY OF Rb-Sr ISOCHRON INFORMATION

SAMPLE	TYPE OF ISOCHRON	NUMBER OF ANALYSES	MSWD*	MODEL**	AGE	INITIAL $^{87}\text{Sr}/^{86}\text{S}$
84091641	Total Rock	9	4	2	1370 $^{+64}$	0.724 $^{+0.002}$
84091644	"	10	34	3	1560 $^{+150}$	0.713 $^{+0.005}$
84091676	"	5	1.8	1	415 $^{+50}$	0.7378 $^{+0.0009}$
84091676	Mineral	6	46	3	348 $^{+3}$	0.7388 $^{+0.0007}$
84091677	Total Rock	11	22	2	1480 $^{+160}$	0.730 $^{+0.016}$
84091681	"	12	1.5	1	1530 $^{+70}$	0.7087 $^{+0.0003}$
84091686	"	8	48	2	1510 $^{+160}$	0.714 $^{+0.004}$
84091689	"	8	1.8	1	1140 $^{+56}$	0.726 $^{+0.002}$

* Mean square of weighted deviates

** After McIntyre et al, 1966.

Table 3-11 Rb-Sr isotopic data for the Redbank Deformed Zone samples. Fractions are listed numerically. The 1-cm slabs cut parallel to the foliation are listed alphabetically.

Rb-Sr Isotopic Data for the Redbank Deformed Zone Samples

SAMPLE		Rb(ug/g)	Sr (ug/g)	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Rb}/^{86}\text{Sr}$	AGE(M)
84091179	A	177.3	242.9	0.75483	2.118	
	B	159.4	236.5	0.75426	1.954	
	C	152.5	246.5	0.75349	1.794	
	D	174.9	230.6	0.75503	2.199	
	E	176.2	239.9	0.75488	2.130	
	F	155.0	235.8	0.75398	1.906	
84091641	1	139.3	158.3	0.77411	2.568	
	2	166.0	166.2	0.78083	2.905	
	4	177.9	163.8	0.78601	3.160	
	7	158.3	171.7	0.77575	2.680	
	8	184.4	178.9	0.78239	2.998	
	A	117.8	159.4	0.76585	2.146	
	D	169.8	169.3	0.78073	2.916	
	G	148.6	159.9	0.77742	2.702	
	I	232.4	218.6	0.78421	3.092	
84091644	1	126.6	207.4	0.75410	1.770	
	2	172.9	189.2	0.77294	2.655	
	3	141.5	198.5	0.75895	2.068	
	4	150.2	200.0	0.76201	2.179	
	5	157.9	194.3	0.76530	2.359	
	6	144.7	203.2	0.75877	2.065	
	A	170.3	194.6	0.76929	2.542	
	B	175.5	185.0	0.77524	2.757	
	C	134.2	201.5	0.75548	1.932	
	E	146.8	202.5	0.76009	2.104	
	biotite	562.3	22.95	1.12241	73.62	356
84091676	A	102.4	298.3	0.74358	0.995	
	B	117.1	266.1	0.74534	1.275	
	C	112.3	271.8	0.74498	1.197	
	D	125.1	254.7	0.74613	1.424	
	E	124.4	260.6	0.74592	1.384	
	F	119.3	287.2	0.74468	1.204	
	G	127.5	254.1	0.74517	1.454	
	H	140.8	262.4	0.74522	1.555	
	I	123.9	272.5	0.74505	1.318	
	biotite	575.3	13.21	1.40489	134.4	348
	epidote	6.007	714.2	0.73807	0.0225	
	plagio- clase	10.40	216.3	0.73975	0.1393	
	k-feld- spar	167.0	348.4	0.74592	0.1393	
	muscovite	214.6	123.9	0.76437	5.029	366
84091677	1	282.9	111.8	0.88547	7.433	
	2	267.3	112.6	0.87726	6.970	
	3	267.2	104.6	0.89076	7.506	
	4	271.9	112.8	0.87883	7.079	
	6	277.0	101.8	0.90448	8.009	
	7	245.4	108.9	0.87053	6.625	
	A	299.6	108.7	0.90176	8.107	
	B	320.6	118.5	0.89623	7.955	
	C	246.3	109.8	0.87037	6.581	
	D	236.8	114.2	0.86047	6.079	
	E	290.3	125.8	0.87116	6.772	
	biotite	1306.0	7.006	4.9726	762.7	380
84091681	1	33.22	337.4	0.71505	0.2845	
	2	21.60	337.8	0.71265	0.1847	
	3	30.42	344.1	0.71433	0.2554	
	4	39.93	348.1	0.71596	0.3315	
	5	35.11	340.7	0.71539	0.2978	
	6	33.31	341.0	0.71491	0.2822	
	B	33.23	339.6	0.71485	0.2827	

SAMPLE	Rb (ug/g)	Sr (ug/g)	$^{87}\text{Sr}/^{86}\text{Sr}$	$^{87}\text{Rb}/^{86}\text{Sr}$	AGE (Ma)
D	32.16	333.7	0.71489	0.2784	
E	29.78	339.2	0.71425	0.2536	
F	27.52	335.1	0.71387	0.2373	
G	26.02	332.8	0.71364	0.2259	
H	17.88	329.8	0.71230	0.1566	
84091686	1	108.8	242.6	0.74136	1.299
	6	164.9	238.6	0.75802	2.005
	7	139.7	217.9	0.75541	1.859
	9	188.6	244.7	0.76130	2.237
	A	138.6	245.0	0.74908	1.640
	C	164.1	225.8	0.75812	2.109
	E	102.5	229.2	0.74154	1.296
	G	109.5	232.3	0.74385	1.366
84091689	1	230.9	283.9	0.76488	2.361
	2	214.0	286.3	0.76182	2.170
	3	221.0	293.0	0.76231	2.189
	5	212.5	295.3	0.76034	2.088
	A	271.6	322.7	0.76635	2.445
	B	255.1	290.3	0.76792	2.553
	C	226.6	285.9	0.76430	2.301
	E	219.4	288.8	0.76239	2.206
	biotite	775.2	25.24	1.39917	94.68
84091632		295.4	164.5	0.79989	5.231
	biotite	1355.0	20.12	1.8645	216.5
84091669		237.9	164.5	0.80663	4.215
	biotite	1216.0	16.37	2.8012	258.4
72933000*	biotite	760.6	9.389	2.2544	269.3
72933001*	biotite	1182.0	6.809	14.019	1154.0
72933002*	biotite	2159.0	12.46	25.441	1709.0
7393003	biotite	813.9	8.462	2.4427	324.9
7393004	biotite	519.9	32.65	0.99216	47.26

* Data taken from Marjoribanks & Black (1974)

All ages are reported or recalculated using the $1.42 \times 10^{-11} \text{ y}^{-1}$ decay constant for ^{87}Rb (Steiger & Jäger, 1977)

Fractions are listed numerically and lcm-thick slabs cut parallel to the foliation are listed alphabetically

Mineral analyses refer to last fraction listed in each case

TABLE: 3-12 Chemical Composition of Type 1 and Type 2
Mylonites from Site R

	8409 1677/4	8409 1676B
SiO ₂	72.35	67.71
TiO ₂	0.41	0.65
Al ₂ O ₃	13.62	14.60
Fe ₂ O ₃	1.06	1.96
FeO	1.95	2.97
MnO	0.04	0.05
MgO	0.71	1.30
CaO	1.94	4.27
Na ₂ O	2.49	2.35
K ₂ O	4.58	2.81
P ₂ O ₅	0.09	0.14
Rb	260	120
Sr	110	270
Th	20	25
Pb	28	11
Y	39	23
U	2.5	1.5
Ga	15	18
As	0.5	0.5
Bi	1	1
Sn	5	2
Nb	8	10
Zr	148	241
Mo	3	3
V	34	71
Cr	10	16
Ba	641	1111
La	40	50
Ce	71	96
Nd	31	40
Pr	7	9
Cs	8	3
Sc	8	10
Be	3	3
Cu	11	8
Li	27	15
Ni	6	9
Zn	41	36

Table 3-13. Correlation of deformation sequences with regional tectonic events in the Arunta Block

GRANULITE TERRAIN	AMPHIBOLITE TERRAIN	REGIONAL EVENT	INFERRED AGE RANGE (Ma); REFERENCE (*)
D1		Early Strangways	1800-1750 (1) 1860±80 (4) 1800 (5)
D2		Late Strangways	< 1750 (1) 1700 Ma (5)
	D1		
	D2	Aileron (Chewings phase)	1700-1600 (1) >1586 ±69 (2)
D3		Anmatjira	1500-1400 (1) 1500-1400 (3) 1470±60, 1440±60 (4)
D4	D3	Ormiston	1050-900 (1) 1053±50 (2) About 1140 (3)
D5	D4	Alice Springs Orogeny	400-300 (1) 400-350 (3) or less

- * (1) Shaw et al, 1984; Black et al, 1983
 (2) Marjoribanks and Black, 1974
 (3) This paper
 (4) Iyer et al, 1976
 (5) Windrim and McCulloch, 1986

TABLE 3-14. Summary of Stratigraphic and Tectonic History in each
Tectonic Province, Arunta Block

EVENT AND APPROXIMATE AGE	NORTHERN PROVINCE	CENTRAL PROVINCE	SOUTHERN PROVINCE
Alice Springs Orogeny 400-300 Ma	Overthrusting, local retrogression	Faulting, local metamorphism up to green-schist	Overthrusting, green-schist metamorphism, zones of intense deformation
Ormiston Event 1050-900 Ma	Local zones of deformation, local granite	Local zones intense deformation, local granite	Amphibolite metamorphism, migmatite, local granite, acid volcanics
Anmatjira Event 1500-1400 Ma	Greenschist metamorphism, 'S- type' granites	Possible migmatite and local granulite metamorphism	Possible granite intrusion
Aileron Event (includes Chewings Phase) 1750-1600 Ma	Granulite metamorphism, many granites, minor pegmatite	Local amphibolite metamorphism at southern margin	Amphibolite metamorphism, 'I- type' granites, local diorite, dolerite, ultramafic rocks
Strangways Event 1800-1750 Ma	Possible local granulite metamorphism, granites in NW and NE	Granulite metamorphism, migmatite, anatectic granite	Not evident
Deposition of Division 3 Early Proterozoic	Quartzite, shale, carbonate, and metamorphosed equivalents	Quartzite, rare pelitic gneiss, schist, and calc- silicate rocks	Metamorphosed quartz arenite, shale, conglomerate
Contact Relationship	Unconformity	Inferred unconformity	Probable unconformity
Deposition of Division 2A: Early Proterozoic	Aluminous and siliceous meta- sediments, calcareous rocks, amphibolite	Pelitic and calcareous rocks, amphibolite	Metasediments, calc-silicate rocks, ortho-gneiss
Deposition of Division 2B: Early Proterozoic	Not evident	Layered granitic gneiss	Layered granitic or granodioritic gneiss, amphibolite
Contact Relationship	Faulted, disrupted by granite	Div. 2B locally unconformable on Div. 1A; elsewhere faulted	Div. 1 thrust over Div. 2B at northern margin
Deposition of Division 1A; Early Proterozoic or earlier	Not evident	Calcareous and pelitic rocks, quartzofeldspathic gneiss	Not evident
Deposition of Division 1B; Early Proterozoic or earlier	Felsic and mafic granulites, overlain by metasediments, Anmatjira Range	Felsic and mafic granulites, sub- ordinate meta- sediments	Not evident

TABLE : 3-15 Summary of previous age determinations in the region of the Redbank Deformed Zone (RDZ) before start of $^{40}\text{Ar}/^{39}\text{Ar}$ dating program

LOCATION	ISOTOPIC METHOD	REFERENCE	AGE (MA)	COMMENT
North of RDZ	Rb-Sr TR	Black et al, 1983	1768±50	Deformation and granulite facies metamorphism: (Late Strangways Event)
	Rb-Sr TR	Black et al, 1983	1728±65	Early Strangways Event
Within RDZ	Rb-Sr biotite	Marjoribanks & Black, 1974	395	Partial resetting
	(1) Rb-Sr TR (2) Mineral - TR	Shaw & Black, in press	350-400	Age of late mylonitisation
	Rb-Sr	Shaw & Black, in press	1400-1500	Age of early mylonitisation
South of RDZ	Rb-Sr Musc-TR	Marjoribanks & Black, 1974	1053±50	Widespread migmatitisation concentrated North of Ormiston Nappe and thrust zone
	Rb-Sr TR	Marjoribanks & Black, 1974	1586±69	Deformation and amphibolite facies metamorphism

TABLE: 3-16 Closure Temperatures

Mineral	Cooling Rate, °C/Ma	Closure Temperature	References
<u>FISSION-TRACK</u>			
Apatite	1	105 ± 10°C	Naeser and Forbes (1978), Zimmerman & Gains (1978), Gleadow & Duddy (1980), Naeser (1981)
	10	120 ± 10°C	
	100	135 ± 10°C	
<u>⁴⁰Ar/³⁹Ar</u>			
Microcline	<5	132 ± 13°C	Harrison & McDougall (1982)
	30	150 ± 13°C	" "
Biotite	1	280°C	Harrison et al (1985)
	10	310°C	
		100	345°C
Muscovite	all	350 ± 50°C	Jäger, (1979)
Hornblende	10	485 ± 30°C	Harrison (1981)
"	30	505 ± 30°C	" "
Hornblende	100	525 ± 30°C	" "

Table 3-17 Summary of K-Ar and $^{40}\text{Ar} / ^{39}\text{Ar}$ ages.

TABLE: 3-17 Summary of K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ ages

Site	Specimen/ Field No.	Mineral	K/Ar Age	$^{40}\text{Ar}/^{39}\text{Ar}$ TF Age
Ar1	87-76 (4175)	Biotite	745.1 ± 6.7	-
Ar2	86-131 (4178)	K-feldspar (Microcline)	-	607.8
Ar3	87-80 (4188)	K-feldspar (Microcline)	631.3 ± 5.6	-
	87-77 (4188)	Biotite	451.3 ± 5.7	-
Ar4	87-79 (1726)	K-feldspar (Microcline)	534.6 ± 4.8	-
	87-83 (1726)	Biotite	642.5 ± 5.7	-
Ar5	86-122 (2066)	Hornblende	1426.9	1391.4
	86-134 (2065)	K-feldspar (Orthoclase)	-	387.5
	87-78 (2065)	Biotite	434.9 ± 3.9	-
Ar6	86-126 (3003)	K-feldspar (Microcline)	511.5 519.5	505.9 ± 2.3
Ar7	87-81 (1360)	K-feldspar (Orthoclase)	679.1 ± 6.1	687.8 ± 3.1
	87-84 (1360)	Biotite	495.0 ± 4.4	-

TABLE: 3-17 (Continued)

Site	Specimen/ Field No.	Mineral	K/Ar Age	$^{40}\text{Ar}/^{39}\text{Ar}$ TF Age
Ar8	87-133 (2087)	K-feldspar (Microcline)	-	$388.8^{+1.9}$
Ar9	86-136 (2090)	Hornblende	-	$1186.6^{+5.2}$
Ar10	86-124 (RWM 865)	Muscovite	1074.7	$1085.9^{+4.3}$
	86-132 (RWM 865)	K-feldspar	-	606.2
Ar11	86-123 (2079)	Muscovite (Microcline)	1124.9	1125.3
	86-125 (2077)	K-feldspar (Microcline)	628.4	643.2
	86-127 (2077)	Biotite	1124.9	-
Ar12	86-135 (2080)	Hornblende	$1138^{+7.1}$	$1155.6^{+4.5}$
Ar13	87-82 (1676)	K-feldspar (Microcline)	$466.1^{+5.8}$	453^{+2}

(see next page for Lats. & Longs)

TABLE: 3-17 (Continued)

SITE	LATITUDE	LONGITUDE
Ar1	22° 58.00'	132° 41.85'
Ar2	22° 55.15'	132° 59.91'
Ar3	22° 57.85'	133° 01.00'
Ar4	23° 15.90'	132° 44.95'
Ar5	23° 24.75'	133° 06.75'
Ar6	23° 26.55'	132° 46.62'
Ar7	23° 23.20'	132° 24.37'
Ar8	23° 37.45'	133° 05.95'
Ar9	23° 39.95'	133° 03.28'
Ar10	23° 37.45'	132° 51.88'
Ar11	23° 47.00'	133° 12.95'
Ar12	23° 46.69'	133° 15.42'
Ar13	23° 20.35'	132° 12.12'

TABLE: 3-18 Apatite Fission Track Results

Site	Specimen Nos.	Apatite FT Age (± 16)	Mean Track Length (μm)
AR3	86-131/4178 (8651-3)	271^{+13}	$12.48^{+0.18}$
near AR5	H625/ (8651-5)	307^{+19}	$14.08^{+0.11}$
AR11	86-123-127/2077 (8651-2)	260^{+19}	$12.19^{+0.22}$

These specimens were collected by the author, and the fission track determinations carried out by P. Tingate, University of Melbourne.

TABLE: 3-19 Estimated Loss of Ar from K-feldspars

Site	Specimen No.	TF Age	% Loss
Ar2	86-131 (4178)	608	67
Ar5	86-134 (2065)	388	95
Ar6	86-126 (3003)	506	81
Ar7	87-81 (1360)	688	65
Ar8	87-133 (2087)	389	91
Ar10	86-132 (RWM 865)	606	78
Ar11	86-125 (2077)	643	64
Ar13	87-82 (1676A)	453	84

Loss is estimated as a cumulative percentage loss of ^{40}Ar assuming an initial cooling age of 1050Ma and an age of 300Ma for the end of the thermal pulse. A zero intercept age was determined by extrapolation to minimise the more obvious effects of excess argon.

Table 3-20 Stratigraphic summary and estimated sedimentation rates for the Pertnjara Group.

NOTES:

1. The Devonian is assumed to span from 355 Ma to 408 Ma. A consensus age of 387 Ma is taken to be reasonable for the base of the Eifelian. The duration of each stage is based on the relative palaeontological unit duration index of Ziegler (1978).
2. The estimated age of 355 Ma for the top of the Devonian (adapted after G. Young, BMR, pers. comm. 1987) places the boundary between the Mansfield Group and the Cerberean Volcanics. The volcanics have a Frasnian Fauna and are intruded by the Barjara Granite dated by Richards and Singleton (1981) at 360 Ma. The unconformably overlying Mansfield Group contains a Carboniferous fauna high in its section and may straddle the Devonian-Carboniferous boundary.
- 3.&4. These represent widely accepted time scales (cf. Williams et al, 1982).
5. These faunal assemblages are described by Young (1985) and Young et al (1987). Fauna 3 is the Late Devonian Palynoflora of Playford et al (1986). Fauna 2B contains *Phyllolepis* sp. which is characteristically Frasnian in Europe but ranges from Eifelian to mid Frasnian in China (G. Young, pers. comm.), a unit previously mapped as Ooraminna Sandstone but considered part of the Hermannsburg Sandstone (M. Owens, BMR, pers. comm., 1987).

Fauna 2A contains both *Bothriolepis* sp. and *Phyllolepis* sp. are present suggesting an age close to the Frasnian/Givetian boundary (see Young, 1985 and Young et al, 1987).

Fauna 1 is dominated by *Bothriolepis* sp. suggesting an age near the Eifelian/Emsian boundary (see Young et al, 1987).
6. Thickness and stratigraphy is from Jones (1970, 1972). The unit mapped in the Hermannsburg Sandstone is the conglomerate Ljiltena Member. The upper Undandita Member of the Brewer Conglomerate accounts for 340m at the top of the section near 133° longitude and occurs in the sub-surface not far above the measured section in the eastern Waterhouse Range. The Undantina Member contains Fauna 3.

TABLE: 3-20 Stratigraphic summary and estimated sedimentation rates for the Pertnjara Group

Unit (Est. age range) (Ma)	Time Scales (age base) Ma				SYSTEM	Faunal/Floral Assemblage	Raw Sedimentation Rate m/Ma; (Total Thickness, m)		
	This Paper (Range, Ma)	Ziegler, 1978 (Range, Ma)	Odin & Gale, 1982	Harland 1984			At 133°C Long. Ca	Ellery Creek	Waterhouse Range
Notes (see below)	1	2	3	4		5	6	6	6
Brewer Conglomerate (5 to 8)	355 [±] 5	350 ca	360 [±] 5 10	360	CARBONIFEROUS				
Hermannsburg Sandstone (2-4)	364 (9)	362 [±] (12)		367	Famennian	3	~450-280 (~2250)	> 192-120 (~2960)	> 66-42 (~330)
	372 (8)	372 [±] (10)		374	Frasnian		150-75 (295)	270-135 (540)	170-85 (335)
Parkes Siltstone (Ca15)	380 (8)	380 [±] 25 (8)		380	Givetian	2A	37 (522)	7 (100)	(absent)
Pertnjara Movement (5-10)	387 (7)	387 [±] (7)	385 [±] 8	387	Eifelian	1			
	397 (10)	397 [±] 17 (10)		394	Emsian				
	402 (5)	402 [±] (5)		401	Seigenian (Pragian)				
Mereenie Sandstone (38±20)	408 (6)	408 [±] 3 (6)	401+10 -5	408	Gedinian (Locktovian)				
Rodingan Movement (40-25)					Silurian			7-15 ⁺ (275)	

Table 3-21 Sequence along the Amadeus Homocline.

TABLE: 3-21 Sequence along the Amadeus Homocline

GROUP FORMATION	Ellery Creek 133° 00'		Ar11-Ar12 133°15'		Hugh River 133°26'	
	Thickness (m)	Cumulative Thickness (m)	Thickness (m)	Cumulative Thickness (m)	Thickness (m)	Cumulative Thickness (m)
PERTNJARA GROUP						
Brewer Conglom- erate	2100		960		500+	
Hermannsburg Sandstone	625	2725	540	1500	430	
Parke Silt- stone	490	3215	100	1600	-	930+
Mereenie Sandstone	275	3490	-	1600	-	
LARAPINTA GROUP						
1. (Eroded)	(400+)		(950+)		(1000+)	
2. Preserved	1275	4765	900	2500	548 nearby	1478
Stairway Sst	(330)				* (1)	
Horn Valley Stn	(135)					
Pacoota Sst	(810)					
PERTAOORTA GROUP						
Julie Formation	480	6642	330	4400	180	3398
Pertatataka Formation	180	6822	240	4640	300	3698
Pioneer Sandstone	195	7017	87	4727	80	3778
Aralka Formation	95	7112	45	4772	-	3778
Areyonga Formation	350	7312	210	4982	220	3998
Bitter Springs Formation	760 ⁺	8072	745 ⁺	5727	420 ⁺	4418
Haavitree Quartzite	250	8472	250+	5977	250+	4668

References: Prichard and Quinlan, 1962
Haines, P.W., 1982
Freeman et al, 1987.

*(1) Covered by Ljiltera Member of Hermannsburg Sandstone

Table 3-22 Estimates of palaeogeothermal gradients for the Ellery Creek Section.

TABLE: 3-22 Estimates of Palaeogeothermal Gradients for the Ellery Creek Section

Method	Temperature (°C)	Preserved Thickness (m)	Maximum Geothermal Gradient °C/km	Estimated Overburden m	Adjusted Geothermal Gradient (°C/km)
Apatite *1	100 ± 10	3500	29 ± 3	500	25 ± 3
CAI Values *2	90 ± 10 *4 20	4200	21 ± 3	500	19 ± 3
Apatite *3	80 ± 10	surface	-	3200	25

- *1 Fission track ages from the Stairway Sandstone show a severe reduction in apparent age suggesting palaeotemperatures of about 100°C (P. Tingate, Melbourne University, pers. comm. 1987)
- *2 CAI values for conodont maturation are 1.0 in units p1 and the top of p2 for the Pacoota Sandstone 4200 m below the preserved top of the section (R. Nicholl, BMR, pers. comm. 1987).
- *3 Surface apatite samples of Brewer Conglomerate have track lengths of 12.5 μm suggesting palaeotemperatures of about 80 ± 10°C (P. Tingate, pers. comm.)
- *4 CAI values of 1.0 suggest a temperature of less than 100°C and more than 50°C (Nowlan and Barnes, 1987)

Table 3-23 Speculative summary of the uplift history of the crustal blocks.

TABLE: 3-23 A Speculative Summary of the Uplift History of the Crustal Blocks

SITE	Active Structure	Thermal Pulse (Approx)			Maximum Inferred Uplift (Km)*5	Inferred Age & Time Span of Uplift (c.a.) *6	Comment
		Start Ma	Peak Ma*4	End Ma			
AR2 (131)	Mount Harris Fault (MF)	390-440*1	380-60 ⁺	350-370 *8	11	Late Devonian 380 to 350±30	
AR5 (134)	Redbank Deformed Zone (RDZ)	400*2 370*3	-	340	11.5	Late Devonian Earliest Carboniferous 370 to 340	Gradual uplift of granulites
AR8 (133)	Ormiston Thrust Zone (ON)	370*3 *7	335	300	11.5	Mid to Late Carboniferous 335 to 300	Uplifted after granulites
AR10 (132)	Amadeus Homocline (AH)	370*3 *7	335-355	300-340	11	Middle to Late Carboniferous 345 (±10) - 300 (±40) and younger	Uplifted after granulites
AR11 (125)	Amadeus Homocline (AH)	370*3 *7	330-350	300-320	11	Middle to Late Carboniferous 340(±15)-310(±15), continue to 260	Uplift after granulites

*1 Peak width assumed to be 40-70 Ma (see Fig. 3-29)

*2 Ar loss spectra suggest gradual and steady uplift between 400 Ma and 350 Ma.

*3 Stratigraphic evidence indicates that rapid synorogenic deposition starts with the Ljiltera (conglomeratic) Member of the Hermannsburg Sandstone at 370-5 Ma

*4 Peak is assumed to be mid-point between start and end of thermal pulse.

*5 Estimated as the depth of burial required for a geothermal gradient of 25°C/km to produce the estimated Ar loss assuming a 50 Ma-square thermal pulse (see Fig. 3-29)

*6 Time from Peak maximum to end of Peak.

*7 By 360-365 Ma green-schist mylonites (observed in the Undandita Member of the Brewer Conglomerate) and presumed to come from the RDZ, were unroofed (see text for further discussion)

*8 Uplift was possibly the Korriddy Movement of Wells & Moss (1983).

Table 3-24 Estimated thermal conductivity for a typical section through the Amadeus Basin.

TABLE: 3-24 Thickness of Lithological Units and Estimated Thermal Conductivities for a Typical Section through the Amadeus Basin

Lithology	Thermal Conductivity (k_i) $\text{Wm}^{-1} \text{K}^{-1}$	Proportion of Sequence (ϕ_i)
Sandstone (orthoquartzite)	3.5	0.51
Siltstone	3.0	0.09
Shale	2.0	0.25
Carbonate (Limestone & Dolomite)	2.9	0.15

- Notes:
1. Conductivities estimated after Cermak et al (1982, 4.1, Fig.2)
 2. Lithological proportions for formations after Shaw et al, in press.
 3. The heat flow (q) Wm^{-2} is given by $q = k \times G$
 where G is the geothermal gradient ($^{\circ}\text{C}/\text{km}$) and k is the thermal conductivity $\text{Wm}^{-1} \text{K}^{-1}$. The deduced value is $70\text{--}87.5 \text{ Wm}^{-2} \text{K}^{-1}$.
 4. The harmonic mean for the thermal conductivity
 k_h is $2.84 \text{ Wm}^{-1} \text{K}^{-1}$ given by $1/k_h = \frac{\phi_1}{k_1} + \frac{\phi_{i+1}}{k_{i+1}} \dots$

CHAPTER 4

BASIN DEVELOPMENT IN CENTRAL AUSTRALIA

Table 4-1 Simplified stratigraphy of the northern Amadeus Basin.

TABLE:4-1 Simplified Stratigraphy of the Northern Amadeus Basin

SEQUENCE		FORMATION	CODE Figs.4.1 4.5	MAX THICKNESS (m)	SYSTEM	SERIES
9	PERTINARA GROUP	Brewer Conglomerate	B	3000+	DEVONIAN	UPPER
		Hermannsburg Sandstone	H	1100		MIDDLE
		Parke Siltstone	P	1000		LOWER
8		Mereenie Sandstone	M	1000	SILURIAN	
7		Carmichael Sandstone	C	150	ORDOVICIAN	UPPER
6	LARAPINTA GP	Stokes Siltstone	S	650		MIDDLE
		Stairway Sandstone	R	600		
		Horn Valley Siltstone	V	430		
		Pacoota Sandstone	F	900		LOWER
		Upper Goyder Formation	G1	300		
5	PERTAOORTA GP	Lower Goyder Formation	G2	300	CAMBRIAN	UPPER
		Shannon Formation	N	715		
		Hugh River Shale	U	785		MIDDLE
		Giles Creek Dolomite	K	396		
		Chandler Formation	D	270		
4		Todd River Dolomite	T	150		LOWER
		Arumbera Sandstone	Upper Lower	1200 NE 3000 NW		
3		Julie Formation	J	150	PROTEROZOIC	UPPER
		Pertatataka Formation	E	700		
		Olympic Formation	O	270		
2		Aralka Formation	L	1020		
		Areyonga Formation	Y	560		
1		Bitter Springs Formation	I	1400		
		Heavitree Quartzite	Q	500		

Table 4-2 Summary of sequences in the northern Amadeus Basin.

TABLE:4-2 Summary of Sequences in the Northern Amadeus Basin

TIME SCALE (Ma)		SEQUENCE	UNITS (See Fig.1)	THICKNESS RANGE (m)	AGE CONTROL	LITHOLOGY	ENVIRONMENT	BASAL UNCONFORM- ITY	INTERNAL UNCONFORMITY			
AGE	TOP	AGE BASE	ALICE SPRINGS OROGENY									
DEVONIAN	360	368	9	Brewer Conglomerate (B)	1500-3000+	Latest Famennian (6)	Conglomerate, pebbly congl. sandstone	alluvial fans	Regional	Local angular unconformity		
		372		Hermannsburg Sandstone (H)	up to 1100			fluvial				
		385		Parke Siltstone (P)	up to 1000	Givetian to Frasnian (1)	siltstone, minor sandst.	lacustrine				
		390		PERTNJARA MOVEMENT								
SILURIAN	408		8	Mereenie Sandstone (M)	up to 1000	Poor; within interval Late Ordovician to Early Devonian (2)	quartz sandstone	partly shallow marine, fluvial- aeolian in upper part	Regional, onlaps all units of sequence 6 in N.E.	Possible break between marine and aeolian facies		
		428?										
ORDOVICIAN	438 LATE	468?	RODINGAN MOVEMENT									
	468	470?	7	Carmichael Sandstone (C)	up to 150	Late Ordovician inferred (2)	Sandstone, silty sand- stone	restricted marine, locally saline	Inferred from abrupt shift in depocentre			
		471?		INFERRED HIATUS								
	MID	476	6	Stokes Siltstone (S)	up to 650	Lower part Middle Llanvirnian (2)	mudstone	restricted marine				
		478		Stairway Sandstone (R)	up to 600	Llanvirnian (2)	quartz sandstone	distal, shallow marine				
EARLY	478		Horn Valley Siltstone (V)	up to 240 or more	Middle to Late Arenigian (2)	black mudstone	shallow marine, below wave base					

TABLE: 4-2 (Continued) 2.

TIME SCALE (Ma)	SEQUENCE	UNITS (See Fig.1)	THICKNESS RANGE (m)	AGE CONTROL	LITHOLOGY	ENVIRONMENT	BASAL UNCONFORM- ITY	INTERNAL UNCONFORMITY
505	6	Pacoota Sandstone (F)	up to 900	Early Arenigian to Payntonian (3)	quartz sandstone	distal, shallow marine		
		Upper Goyder Formation (G1)	up to 300	Payntonian (3)	sandstone	marine	Faunal break ironstone	
				HIATUS				
525	5	Lower Goyder Formation (G2)	up to 300	Mindyallan (3)	sandstone, carbonate	marine		
		Shannon Formation (N)	375-715	Late Mindyallan & older (7)	oolitic carbonate, flat pebbles congl, shale	shallowing sea		
		Hugh River Shale (U)	485 ⁺	E to M Cambrian (2)	mudrock	marine		
540		Giles Creek Dolomite (K)	220-383	Templetonian to Ordian (3)	dolostone, mudrock	shallow marine		
		Chandler Limestone (D)	80-270 In S.E.	Unfossiliferous E. Cambrian? (Ordian or older) (2)	limestone, chert	restricted evapor. In N.W. red proximal sands	Disconformity	
				HIATUS				
570	4	Todd River Dolomite (T)	up to 130	Atabanian to E. Lenian (4), (5)	dolostone	shallow marine to emergent		
605								

CAMBRIAN

LATE

MIDDLE

EARLY

TABLE: 4-2 (Continued)

3.

CAMBRIAN	TIME SCALE (Ma)	SEQUENCE (est)	UNITS (See Fig.1)	THICKNESS RANGE (m)	AGE CONTROL	LITHOLOGY	ENVIRONMENT	BASAL UNCONFORM- ITY	INTERNAL UNCONFORMIT
CAMBRIAN	EARLY	585	Arumbera Sandstone (A) (Lower Cleland Sandstone)	NW: 3000 ⁺ NE: 1200	Earliest Cambrian (2)	red arkosic sand, shale	deltaic, mixed marine and fluvial		Break at base of Cambrian inferred by correlation with Toomba Movement (Georgina Basin)
		605							
		625	Arumbera Sandstone (Z)	"	Latest Precambrian (2)	red arkosic sand, shale	fluvial, conglomeratic and proximal to S. and W.	Disconformity inferred by onlap to south	"
		630							
PROTEROZOIC	LATE	635	Julie Formation (J)	40-150		oolitic dolostone, sandstone	marine, shallowing upwards		
		655	Pertatataka Formation (E)	130-700		red and green mudrock	marine with terrigenous influxes		Disconformit at base of Pertatataka Formation
		680	In NW: Pioneer Sandstone	55-170	Marinoan glaciation (660-680?Ma;8)	arkosic sandstone	shallow marine		"
		680	In NE: Olympic Formation (O)	160-270	"	diamictite	marine	Regional, 1100m + erosion indicated by stratigraphy of clasts in Olympic Formation	"

TIME SCALE (Ma)	SEQUENCE	UNITS (See Fig.1)	THICKNESS RANGE (m)	AGE CONTROL	LITHOLOGY	ENVIRONMENT	BASAL UNCONFORM- ITY	INTERNAL UNCONFORMITY
				SOUTH RANGE MOVEMENT				
705	3							-
735	2	Aralka Formation (L)	up to 1020		black pyritic mudrock, minor sandstone, carbonate	deeper marine minor shallow-sea marine		-
760		Areyonga Formation (Y)	up to 560	Sturtian glaciation (750-Ma; 8)	conglomerate, arkosic sandstone, local diamictite	glacial marine	2500m + erosion indicated by stratigraphy of clasts	-
825				AREYONGA MOVEMENT				
	1	Bitter Springs Formation (I)	1400 ±		carbonate, mudrock, basalt (spilite) evaporite in middle part, cherty-dolostone, red mudstone in upper part.	shallow marine restricted & evaporitic in middle and final phases.		
850		Heavitree Quartzite (Q)	200-500+		quartz sandstone	shallow marine with fluvial influxes	Major non-conformity on basement	
865								
900				Emplacement of Stuart Dyke Swarm			Rb-Sr date (9)	
				Rapid Uplift				
1100				Ormiston Tectonothermal Event			Rb-Sr date (10)	

GENERAL REFERENCES: TABLE: 4-2

Wells et al (1970); Shergold et al (1985); Kennard & Nicoll (1986)

AGE CONTROL REFERENCES

1. Young (1984)
2. Kennard & Nicoll (1986)
3. Shergold (in press)
4. Laurie & Shergold (1984)
5. Kruse & West (1980)
6. Playford et al (1976)
7. Gilbert-Tomlinson in Wells et al (1970)
8. Preiss & Forbes (1981)
9. Black et al (1980)
10. Marjoribanks & Black (1974); Shaw & Black (in press)

Table 4-3 Correlation chart for Proterozoic and Early Cambrian units in the central Australian basins and in the Adelaide Geosyncline.

AGE	N. AMADEUS BASIN		ADELAIDE GEOSYNCLINE		W. GEORGINA BASIN	NGALIA BASIN	OFFICER BASIN		
early Middle Cambrian	Giles Creek Dolomite (300m)		Lake Frome Group	Kannantoo Group	Arthur Creek Formation (129m)	Bloodwood Fm (270m)	Lennis Sandstone		
	Chandler Limestone (270m)		Aroona Limestone (57m)			Walbiri Dolomite (250m)			
late Early Cambrian	Todd River Dolomite (130m)		Billy Creek Formation (817m)	Normanville Group (500m) (includes Truro Volcanics)	Errarra Formation (129m)		Kulyong Volcs (117m)		
			Wilkawillina Limestone (240m)						
early Early Cambrian	Arumbera Sandstone 364 (460m)		Parachilna FM	Mount Baldwin FM (230m)	Yuendumu Sandstone II (280+)		Babbagoola Beds (141m)		
			Uratanna FM						
Vendian	Arumbera Sandstone 162 (740m)		Wilpena Group		Mopunga Group (510m)	Yuendumu Sandstone I (420m)	Punkerrri Beds (1200m)		
			Pound Subgroup (3000m)						
	Julie FM (150m)		Wonoka Formation (460m)						
	Pertatataka FM (180-700m)		Bunyerloo FM (700m)			Elkera FM (257m)			
	Cyclops Member		ABC Range Quartzite (1800m)			Grant Bluff FM (150m+)			
	Gaylad FM		Brachina Subgroup (1200m)			Elyuah FM (100m)			
			Nuccaleena FM (10m)			Thomba Movement			
	Olympic Fm (290m)	Pioneer Sandstone (55-170m)	Willochra Subgroup (700m+)	Yeralina Subgroup (2100m)		Oorabra Arkose (10-1000m)	Mount Doreen FM (97m)	Unnamed silt., sst., mnr tillite (600m)	
	Riphean	South Range Movement		Angapena FM (1300m)		Rinkabeena Movement		Rodda Beds (1200m)	
		Aralka FM (1020m)	Limbla Memb. (144m)	Brighton Limestone (300m)				Tapley Hill FM (700m)	
		Tapley Hill Formation (2000m)							
				Rinkabeena Shale (100m)					
Areyonga FM (1020m)		Sturtian Tillite (400m+)	Appila Tillite (1500-2100m)	Mount Cornish FM (680m)	Naburula FM (8m+)				
	Areyonga Movement		Yudnamutana Subgroup (6000m)	Benda Silt. Pualco Tillite (3300m)			Wantapella Volcs. (290m)		
							Chambers Bluff Tillite (520m)		
		Sturtian Tectonism							
		Burra Group	Belaire Subgroup (3600m)				Unnamed silt., shale, quartzite (1000m)		
		Saddleworth FM (4000m)					Wright Hill beds (3400m)		
		Auburn Dolomite (1200m)							
		Skillogallee Dolomite (4000m)		Yackah beds (26m)	Albinia FM (500m)	Pindiyin beds (430m)			
	Bitter Springs FM	Emeroo Quartzite (1400m)	Aldgate Sandstone (1200m)		Vaughan Springs Quartzite (2500m)		Townsend Quartzite (370m)		
	Heavitree Quartzite (500m+)								
	Stuart Dyke Swarm		Callanna beds						
			Beda Volcanics						
			Backy Point beds						

SEE CAPTION TO FIG. 4-3 FOR REFERENCES

Table 4-4 Correlation charts for Palaeozoic units in the central Australian basins and the Canning Basin.

TABLE: 4-4 Correlation chart for Palaeozoic units in the Central Australian Basins and the Canning Basin (see caption Fig. 4-2 for references)

AGE	N. AMADEUS BASIN	NGALIA BASIN	W. GEORGINA BASIN	CANNING BASIN
Carboniferous		Mount Eclipse Sandstone (±2400m)		Piker Hills Fm, Virgin Hills Fm, Nullara Limestone
Late Devonian	Brewer Conglomerate (1500-3000m±)			
	Hermannsburg Sandstone (1100m)	Kerridy Movement		
Middle Devonian	Parke Siltstone (1000m)	Kerridy Sst. (±703m) (or older)	Dulcie Sandstone (1620m±)	Pillara Fm, Mellingerie Fm, Tandgallee Fm, Poulton Fm, Wortel Fm
Early Devonian	Pertnjara Movement Mereenie Sandstone (1000m)			Carribuddy Group
Silurian	Rodingan Movement	Djagamara Movement	Rodingan Movement	
Ordovician	Carmichael Sst. (150m)			Mite Fm (137m)
				Goldwyer Fm (430m)
	Stokes Siltstone (650m)		Eroded interval	
	Stairway Sst. (600m)	Djagamara Fm (320m)		
	Horn Valley Siltstone (240m)		Nora Fm (113m)	Willara Fm (344m)
Late Cambrian	Pacoota Sst. (900m)		Tomahawk beds (200m)	Nambett Fm (300m)
	Goyder Fm (Upper) (300m)	Bloodwood Movement		
Middle Cambrian	Goyder Fm (Lower) (300m)		Arrinthrunga Fm (900m)	
	Shannon Fm (715m)			
	Hugh River Sh (485m)			
	Giles Creek Dol. (383m)		Arthur Creek Fm (485m)	Gum Ridge Fm
	Chandler Ls (270m)	Bloodwood Fm (270m)		Andagera Fm

Table 4-5 Correlation between unconformities and major orogenic events elsewhere.

TABLE 4-5 Correlation between Unconformities and Major Orogenic Events Elsewhere

Estimated Age (Ma) (Range Uncertain)	Event	Correlation	Nature	Distribution	References (see below)
320-370	Alice Springs Orogeny	Mt Eclipse Orogeny	Thrusting, faulting nappe formation	Central Australian Basins	1
			Folding	Tasmanides: Hill End Trough	2
			Warping, folding, block faulting	Drummond, Darling and Adavale Basins Warnabin Trough	3
			Localised faulting	S. Lachlan Fold Belt	4
					8
385-390	Pertnjar Movement	Tabberabberan Orogeny (380-390Ma)	Folding	S. Lachlan Fold Belt	5
					6
428-468	Rodingan Movement	Benambran Orogeny (430-440Ma)	Discontinuity	Adavale & Darling Basins	15
			E-W folding, strike-slip faulting. Widespread	S. Lachlan Fold Belt	7
			NE folding Hiatus over much of Australia from mid-Ordovician	Thomson Fold Belt	5
					8
					9
508-518	Hiatus at base of sequence 6	Delamerian (about 505-520Ma)	D ₁ folding about 505- 520Ma D ₂ folding about 480-495Ma	Kanmantoo Fold Belt	11
					12
					13
580-605+	Huckitta Movement (Georgina Basin)	Inferred in N. Amadeus Basin Pulses of Petermann Ranges Orogeny	Erosion of top of Mopunga Group	Georgina Basin	3
			(Inferred folding may be Alice Springs Orogeny folds that die out up section)		
			Petermann Ranges Nappe	S. Amadeus Basin	1
			Hiatus below and within Yuendumu Sandstone	Ngalia Basin	2
Duttonian Tectonism				Adelaide Geosyncline	

TABLE 4-5 (Continued)

Estimated Age (Ma) (Range Uncertain)	Event	Correlation	Nature	Distribution	References (see below)
680-700	South Range Movement	Rinkabeena Movement	Mild regional unconformity	Ngalia & W. Georgina Basins	2
			Unconformity between Pinyinna & Winnall Beds	S. Amadeus Basin.	1
800-750	Areyonga Movement	Vaughan Springs Movement	Block faulting precedes uplift and regional erosion	Ngalia Basin	2
				Georgina & Amadeus Basins	
865-900	Arunta Movement		Uplift and erosion following emplacement of Stuart Dyke Swarm	N. Amadeus Basin	10
1200-1100	Ormiston Tectothermal Event	Kulgeran Tectonism			16

PRINCIPAL REFERENCES:

1. Wells et al, 1970
2. Wells & Moss, 1983
3. Freeman, 1986
4. Powell et al, 1977; Powell, 1984
5. Fergusson et al, 1986
6. Ramsay & VandenBerg, 1986
7. Degeling et al, 1986
8. Murray, 1986
9. Webby et al, 1981
10. Black et al, 1980
11. Parker, 1986
12. Shergold et al, 1985
13. Shergold, 1987
14. Harrison, 1980
15. Douth & Nicholas, 1978
16. Wilson et al, 1960 cf. Webb, 1985

Table 4-6 Simplified flexural parameters for the Amadeus Basin.

TABLE: 4-6 Simplified Flexural Parameters for the Amadeus Basin

Sequence	Unit	Maximum Thickness (m)	Estimated Basin Half Width (km)	Crustal Shortening X(km)	Half Width to Zero Deflection X ₀ (km)	Forearch Half-Width X _{bu} (km)	Flexural Parameter Broken Plate α_b (km)	Flexural Parameter Unbroken Plate α_u (km)	Effective Lithospheric "Thickness" H (km)
9C	Brewer Cong.	3000+	25, 75*						
9B	Ljiltera M.		120	32	152		96.8		42.0
9B	Hermannsburg Sst.	1100	160±10	32	192±10		122.0		57.2
9A	Parke Siltln.	1000	100 (in wst) 140 (arch width)	14	114	140	72.6 59.4		28.6 21.9
8	Mereenie Sst.	915	140	2	142+		90.4	(60.3)	22.4
6S	Stairway Sst. & Stokes Siltln.	1250	220	56	276			117.1	54.2
6P	Pacoota Sst. & Horn Valley Siltln.	946 1140	120±5 120±5	56 56	176±5 176±5		112.0	74.7	51.0 29.7
5	Cleland Sst. Carbonates	1060 1300	120 120	2 35	122 155			51.8 65.8	18.3 25.1
4	Arumbera Sst.	3000 wst 1200 est	110 65	37 35	147 100			62.4 42.4	23.4 14.0
3(N)	Pertatataka & Julie Fms, Pioneer Sst.	700\$ (1372)	120±15	56		176±15	74.7		29.7
3(S)	Winnall beds	2135	145+	75+		220+	93.4		40.1
2(N)	Aralka Fm Areyonga Fm	300\$ (1580)	50	15		65	Secondary Feature		
2(S)	Inindia beds	2135+	140+	75+		215+	91.2		38.8

* Assumed to be controlled by surficial processes

\$ Thickness at central-northern edge of basin (Ellery Creek)

TABLE 4-6 (Continued) : Summary of Simplified Flexural Parameters adopted for the Amadeus Basin

Assuming the width of the basin is controlled by a simple horizontal compressive force acting on a broken elastic plate, or alternatively, by a vertical line (sediment) load acting on an unbroken plate:

Estimates of crustal shortening (km): Alice Springs Orogeny - RDZ (Marjoribanks, 1976) = 20±5; ON (Marjoribanks, 1976) = 14±5 SN = 6±3 (Marjoribanks, 1976) AH = 6.5±3 (method of Erslev, 1986; AH is post deposition) Total shortening (RDZ, ON, AH) ~ 40-60km (after abbreviations as in Figures)

Lambeck et al, in press) GT (Wells et al, 1970) = ?14 -15; Late thrusting/folding = 2 (Wells et al, 1970)

Petermann Ranges Orogeny - PRN = 64 (Forman, 1966) Late Folding = 8 (Wells et al, 1970)

Flexural Parameters are given by:

(1) broken plate $\alpha_b = 2x_0 / \pi$; $4x_{bu} / 3\pi$ where $\alpha^4 = D / \Delta\rho g$

(2) unbroken plate $\alpha_u = 4x_0 / 3\pi$; x_{bu} / π

Effective elastic thickness (m) of the lithosphere:

adopting Young's Modulus (E) = 0.6E11Nm⁻²

$H^3 = 3\alpha^4 \Delta\rho g (1 - \nu^2) / E$

Poisson's Ratio (ν) = 0.5 (assuming an incompressible plate)

Foundation Modulus (F_{mod}) = 2 2540 Nm (i.e. deposited below sea level)

Mantle density = 3.3 Mg m⁻³

Flexural Rigidity

$D = EH^3 / 12 (1 - \nu^2)$

Vertical Line Load

$V_0 = 4D_0 W_{max} / 3$ for broken plate) Turcotte & Schubert (1982)

$V_0 = 8D_0 W_{max} / 3$ for unbroken plate) (eqns 3-131, 3-141)

Horizontal force

$N = \omega_0 \Delta\rho g \alpha / 2 \sin \phi \cos \phi$ where ω_0 is the maximum deflection (Gunn, 1947), ϕ is the dip of the fault assumed to be 45°

Compressive Stress

$N = \omega_0 \Delta\rho g \alpha$ for $\phi = 45^\circ$

$S = N/H$

Table 4-7 Physical properties of sediments.

TABLE: 4-7 Physical Properties of Sediments

Sediment Type	Minimum Porosity Parameters				Maximum Porosity Parameters				Bulk Grain Density (t/m ³)
	Deep Level		Shallow Level		Deep Level		Shallow Level		
	Depth to Change Km	Depth to Change Km	Deep Level	Shallow Level	Depth to Change Km	Depth to Change Km	Deep Level	Shallow Level	
	φo	c	φo	c	φo	c	φo	c	
Sandstone	0.20	0.48	0.20	0.48	0.29	0.216	0.4	0.54	2.60-2.68 *2 (2.65)
Siltstone	0.25	0.325	0.25	0.325	0.42	0.375	0.6	1.09	2.66-2.68 *2 (2.68)
Shale	0.37	0.47	0.53	1.19	0.55	0.475	0.7	1.173	2.72 *2 (2.72)
Carbonate	0.37	0.40	0.36	0.40	0.45	0.40	0.45	0.40	2.75-2.80 *2 (2.80)
Average *1	0.27	0.45	0.31	0.81	0.38	0.32	0.49	0.73	*2 (2.704)

Foot Notes: *1 mix is in ratio ss: st: sh: cb of 0.9: 0.25: 0.15: 0.51.
*2 adopted value

Notes: Constants for clastics applied in equation 1 are modified after compaction data in Bond & Kominz (1985) and constants for carbonate are estimated from data in Schmoker & Halley (1982)

CHAPTER 5

MODELS FOR BASIN FORMATION

IN

CENTRAL AUSTRALIA

Table 5-1 Inferred sequence of Cambrian rifting events.

TABLE : 5-1 Inferred Sequence of Cambrian Rifting Events

Inferred Stage	Time Span (Ca)	Episode (Est. Start Ma)	Inferred Mechanisms	Subsidence/Uplift	Reference Formations
Post-Rift Sag Phase	70Ma	6	Slowing thermal contraction & thickening of lithosphere	Decreasing subsidence	Horn Valley Siltstone
		(508)			Pacoota Sandstone
			Compressive stresses	Short-lived, slight, widespread uplift	U. Goyder Fm
		(528)			
Transitional Phase		5	Rapid cooling, and contraction of lithosphere	Rapid subsidence, widespread transgression	L. Goyder Fm
				Rapid subsidence	Giles Creek Dolomite
		(555)		Slow subsidence	Chandler Formation
		(563)	Thermal peak, lithospheric expansion	Slight uplift	
Rifting	15Ma	4	Extensional detachment zone active	In NW: uplift & Volcanism	Antrim Plateau Volcanics
		(570)		In SE: slight widespread subsidence	Todd River Dolomite (A.B.) Errarra Fm (G.B.)
		4	Reactivation of step in detachment zone (see below)	Slight uplift followed by localised subsidence	Arumbera Sandstone 3 & 4
		(585)			
Incipient Rifting		4	Stretching below mid-crustal detachment zone	Slight regional uplift	
		(605)			
		4	Ramp syncline above step in mid-crustal detachment zone	Localised subsidence, contraction of basin	Arumbera Sandstone 1 & 2
		(625)			
		4	Stretching below mid-crustal detachment zone	Inferred slight uplift	
		(630)			

FIGURES

CHAPTER 1

INTRODUCTION

Figure 1-1 The distribution of the central Australian basins in relation to other basins and to basement regions in Australia.

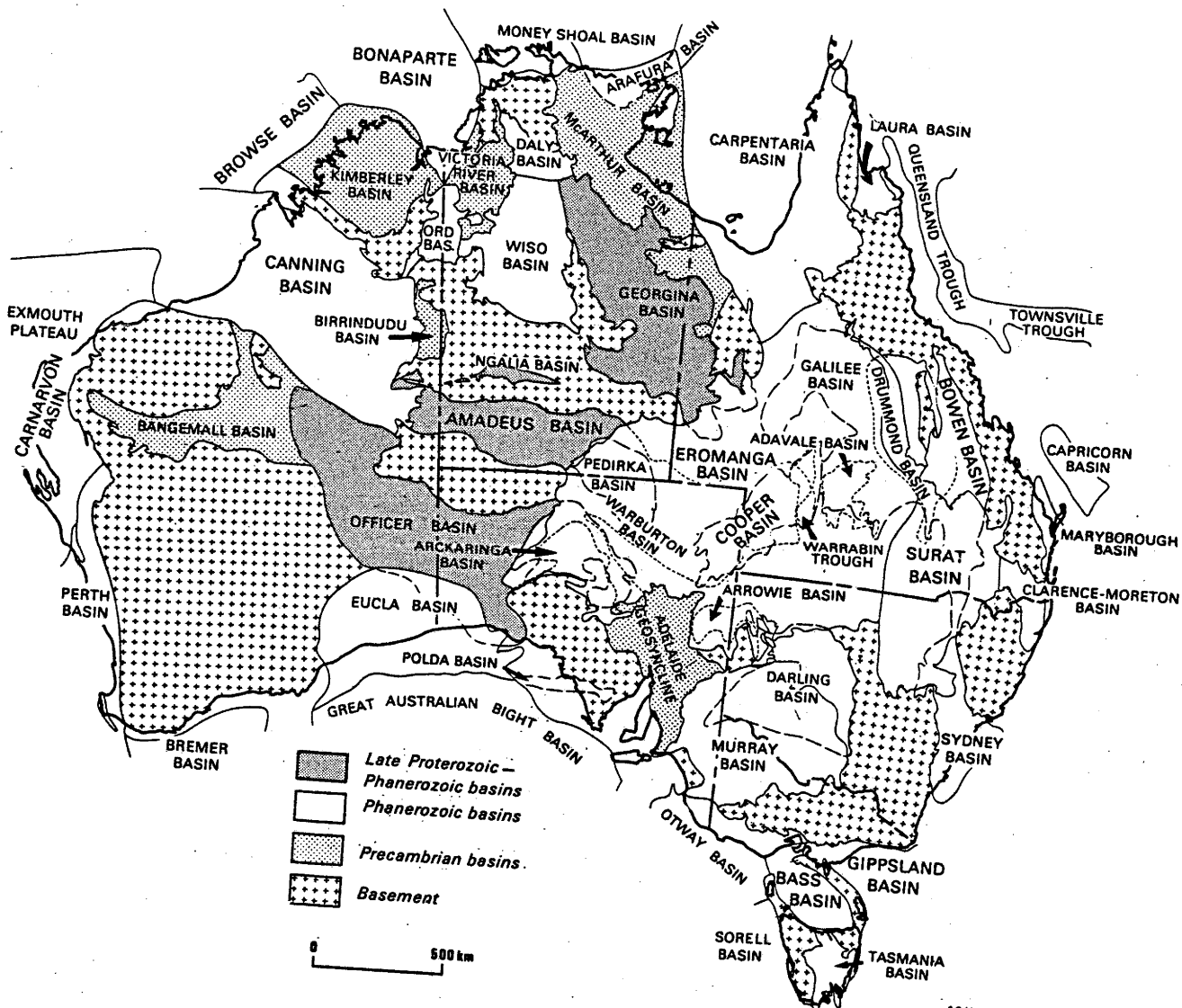


Figure 1-2 An outline of basin-forming mechanisms showing the relationship between basin subsidence and uplift in the adjacent hinterland, in addition to other key parameters.

Figure 1-2 (i)-(iv) Gravitational and compressional models

(i) Simple loading

(a) The variation in basin width as a function of flexural rigidity. The effect shown is for a two-dimensional load of density 2.4 tonne m^{-3} and a foreland sediment load of the same density on an elastic lithospheric plate (after Beaumont, 1981 fig. 9).

(b) Subsidence in relation to uplift in the adjacent thrust belt in foreland loading models. Lines 1 and 2 show the maximum, cumulative thickness of sediment as a function of maximum topographic height in the thrust belt. The plots are for an elastic plate of specified flexural rigidity (after Jordan, 1981 Fig. 15). Arrow 3 is a schematic representation of those parameters for a viscoelastic plate (relaxation constant 27.5 Ma) where the height of the thrust belt was reduced by erosion (after Beaumont, 1981 Fig. 17).

(ii) Foreland Basin Model

(a) The formation of a foreland basin by successive addition of thrust loads. The depocentre moves progressively away from the advancing thrust (after Beaumont, 1981 Fig.3).

(b) Observed subsidence (km) as a function of time (Ma) caused by thrusting in the Cordillera of North America. The rate of subsidence is observed to increase with time. Individual thrust sheets may remain active for up to 150 Ma (after Kominz and Bond, 1986).

(iii) Tilted-block Models

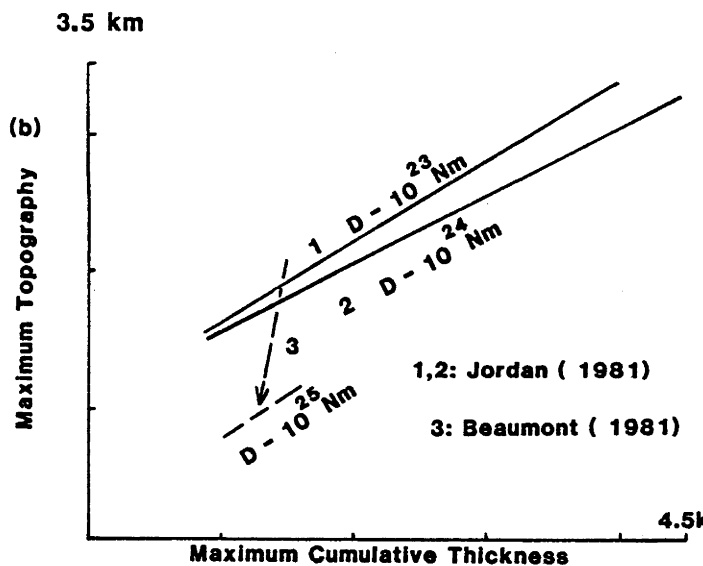
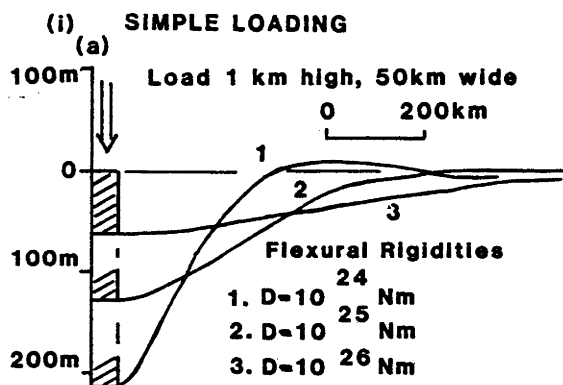
(a) The relationship between the degree of tilting and crustal shortening. The basin depocentre shows minimal migration during the life of the basin (after Lloyd, 1985 and Beaumont pers. comm., 1986).

(b) The relationship between basin subsidence and uplift in the hinterland for the tilted-block model (shaded area, references as above). Curves 1,2 and 3 show the range of values for the plot predicted by the flexural, viscoelastic model of Lambeck (1983).

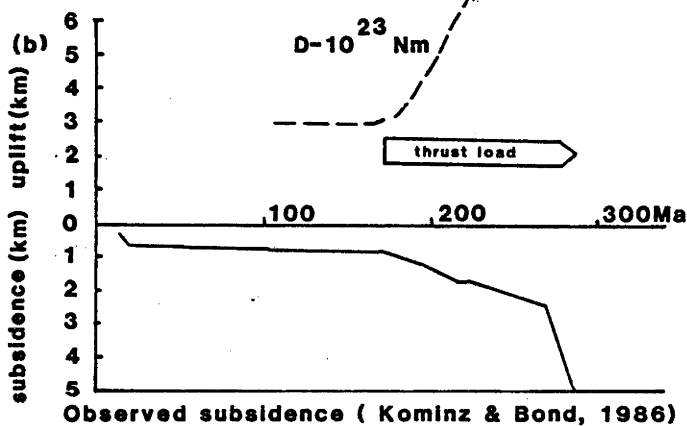
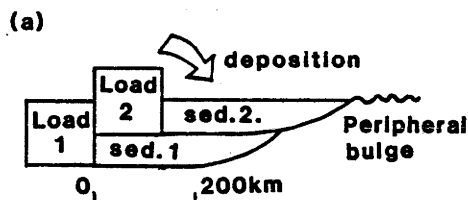
(iv) Compressional Flexure Models

(a) Schematic representation of the model portraying enhanced growth of perturbations in the lithosphere due to erosion of uplifted regions and the infilling of depressions with sediment. Failure would occur on through-going faults if the stress differences became excessive.

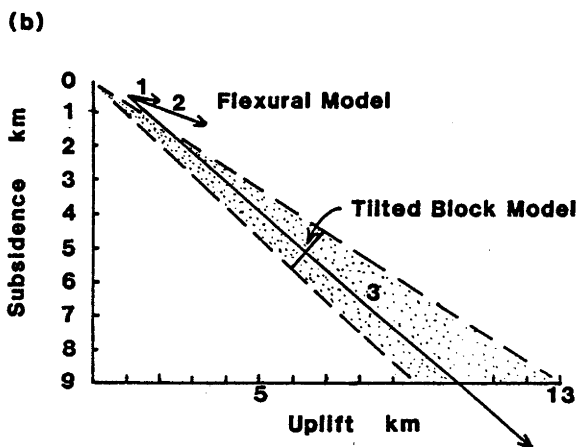
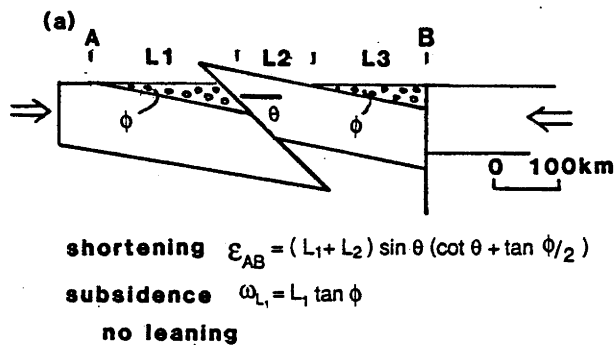
(b) A schematic representation of the time-delay required for viscoelastic relaxation to take place and the lithospheric perturbations to amplify. Note that the magnitude of the upwarps may exceed the amount of subsidence.



(ii) **FORELAND BASIN MODEL**



(iii) **TILTED BLOCK MODEL**



(iv) **COMPRESSIONAL FLEXURAL MODEL**

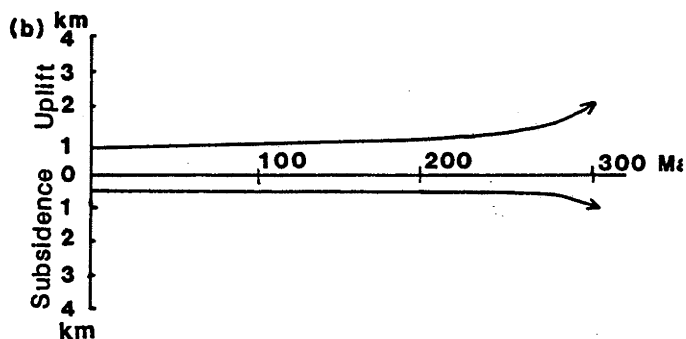
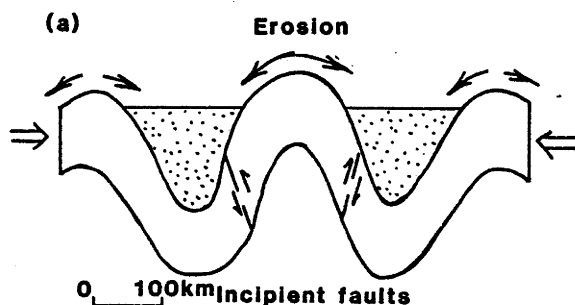


Figure 1-2 (v)-(vii) Thermal and Extensional Models

(v) Thermal Model: Schematic representation showing-

- (a) Topography produced by thermal expansion of the lithosphere
- (b) Subsidence due to isostatic adjustment to mantle upwelling
- (c) Accentuation of the subsidence as a result of thermal contraction of the lithosphere and by the addition of a sediment load.
- (d) Schematic representation of the uplift and subsidence history predicted at continental margins. Curve 1 = dashed line shows shoulder formation at the margin of a thermal basin (Mareschal, 1981; and Middleton, 1984). Curve 2 = exponential decay of subsidence with time for a thermal time constant of 50 Ma and assuming loading with sediment of density 2.6 tonne m^{-3} (Sleep, 1972; 1076). Curve 3 = the decay of subsidence as the square root of time (Ma) for oceanic lithosphere assuming a sediment density of 2.4 tonne m^{-3} (Turcotte and Ahern, 1977).

(vi) Lithospheric Stretching Models

(a) Rift basins formed by stretching of the crust (C) and subcrustal lithosphere (SL) by pure shear (cf McKenzie, 1978). Initial subsidence occurs during isostatic upwelling of the asthenosphere. Shoulder uplift at the margins of the basin is limited to 1-2 km.

(b) Rift basin formed by simple shear on a low-angle detachment zone (Wernicke, 1981; 1985). Shoulder uplift (up to a few km) may occur at the continental plate margin of an over-riding, passive plate (Lister et al, 1986; 1987).

(c) The transition from a rift phase to a sag phase is predicted to be marked by a 'break-up' unconformity. For fault dips of θ and an angular discordance at the 'unconformity' of γ the stretching factor (β) is specified for pure shear stretching: see (e) (Le Pichon and Sibuet, 1981).

(d) A phase of widening of the region of subsidence is predicted for both simple shear and pure shear models as the lithosphere cools and thickens.

(e) Subsidence curves for the pure shear stretching. Curve 1 = subsidence during syn-rift faulting. Curve 2 = subsidence induced by a thermally contracting lithosphere. Three curves are shown for various amounts of stretching (β). Extreme stretching eventually leads to the production of oceanic crust.

(vii) Mantle Plume Model

(a) The lithosphere is modeled in two-dimensions as a thin viscous plate. Extension is induced by ductile flow away from the region which is dynamically uplift by the mantle plume (Houseman and England, 1986). Significant subsidence may occur in the region of sustained uplift and erosion, once the plume is removed. Uplift of 1-3 km is required by the model, depending on the geotherm, to induce spreading and allow later subsidence.

(b) Extension of the lithosphere leads to upwelling of the asthenosphere. Rapid subsidence starts once the mantle plume starts to decay.

(c) Subsidence continues as the lithosphere contracts and cools, and the depression becomes loaded by sediment.

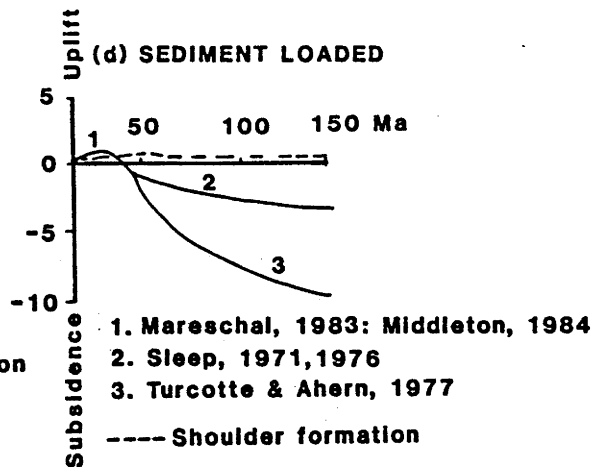
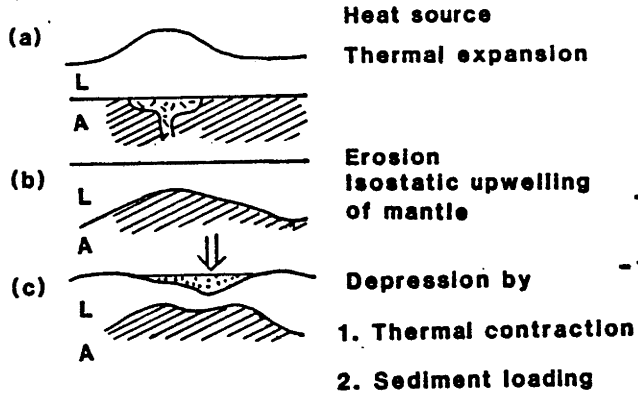
(d) Basement elevation relative to sea-level predicted by the mantle plume model of Houseman and England (1986).

Curve 1 represents 1.2 km of initial uplift which continues as extension proceeds for 25 Ma.

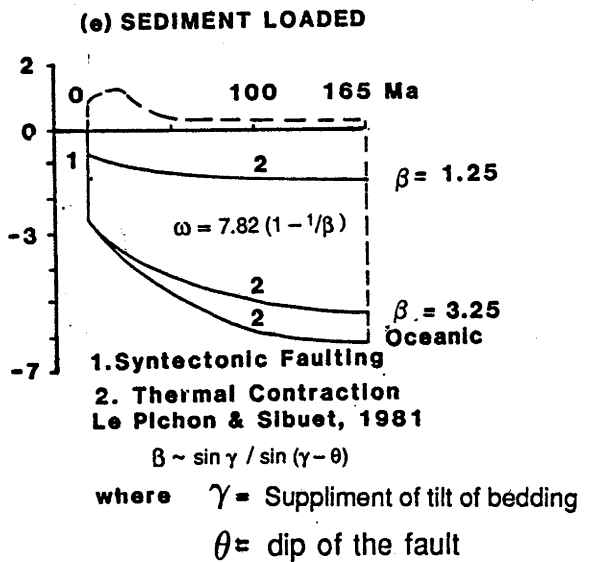
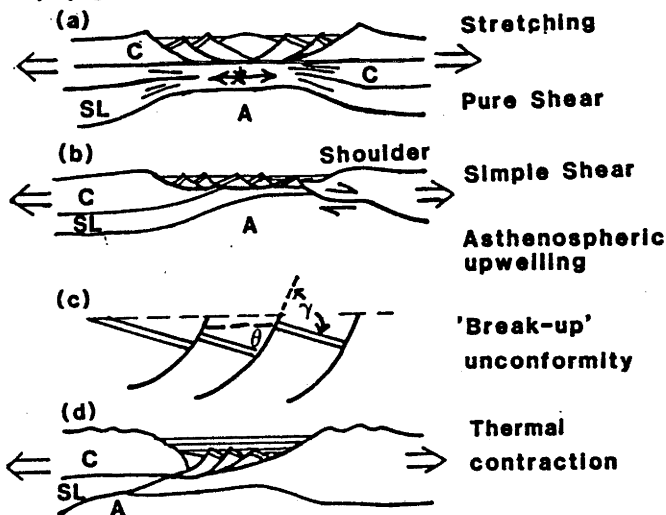
Curve 2 represents rapid subsidence caused by removal of the mantle plume.

Curve 3 represents exponentially decreasing subsidence induced by a thermally contracting lithosphere.

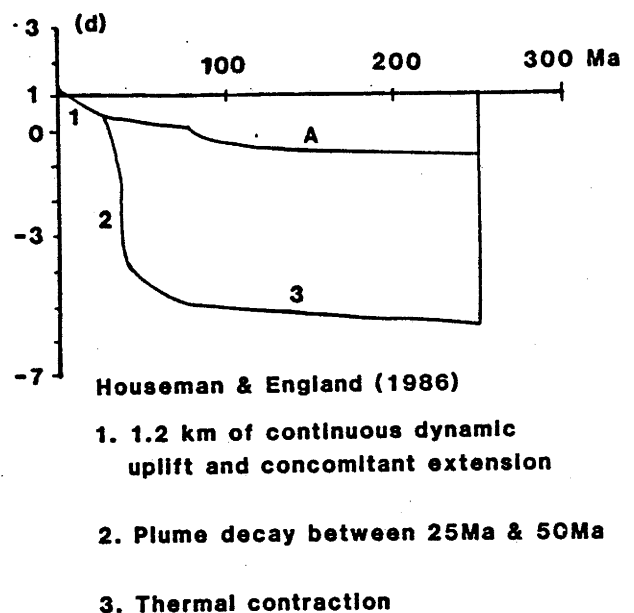
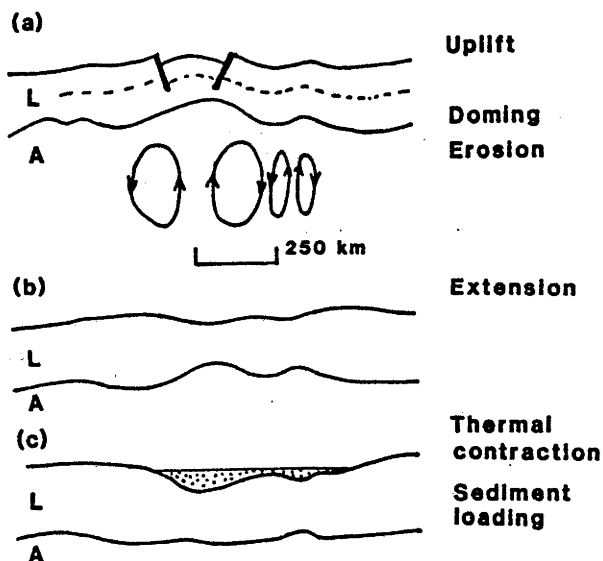
(v) THERMAL MODELS



(vi) STRETCHING MODELS



(vii) MANTLE PLUME MODEL



CHAPTER 2

CRUSTAL STRUCTURE IN CENTRAL AUSTRALLIA

Figure 2-1 The distribution of the main basins and structural features in central Australia, showing the outline of the main sedimentary basins and the principal deformed zones.

1 = Oblique profile, Redbank Zone (Fig. 2-15).

2 = 133° E Longitude profile (Fig. 2-14).

3 = Arunta profile (Fig. 2-3).

4 = Redbank profile (Fig. 2-4).

5 = Ellery Profile (Fig. 2-5).

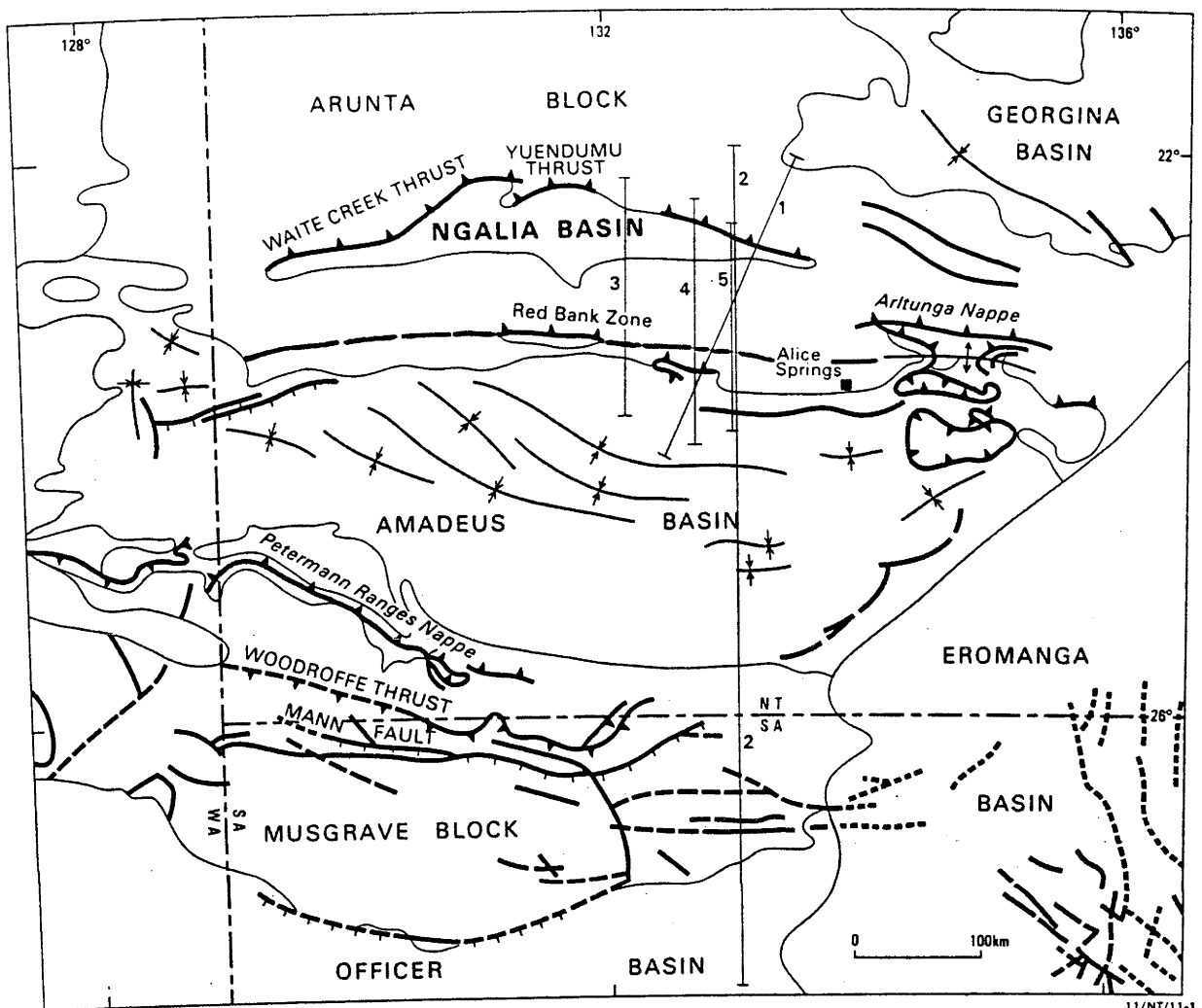
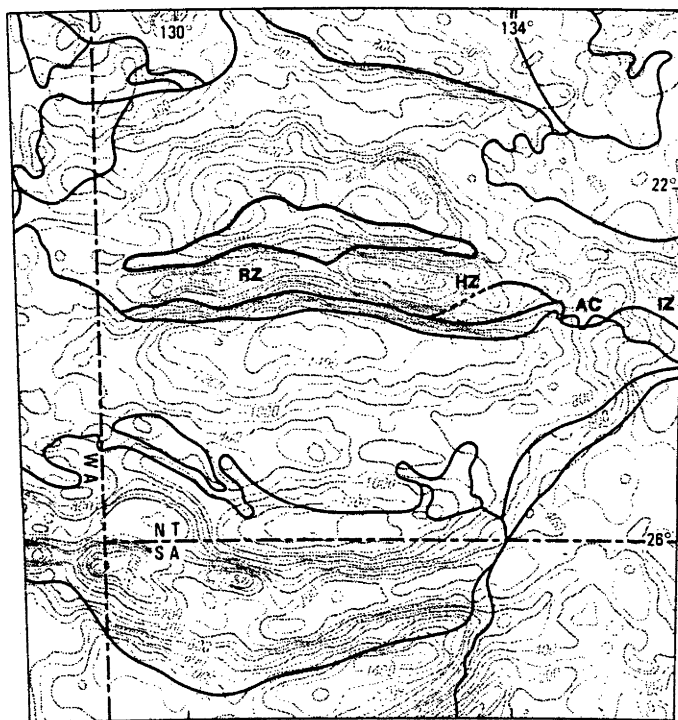


Figure 2-2 Bouger anomalies in central Australia and their relationship to the basin margins.



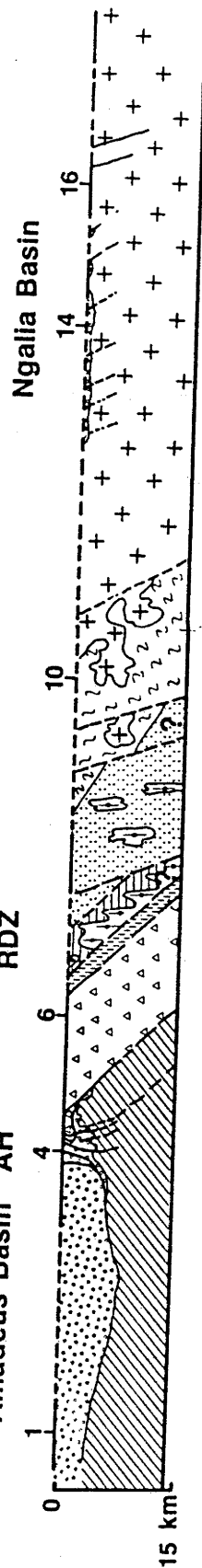
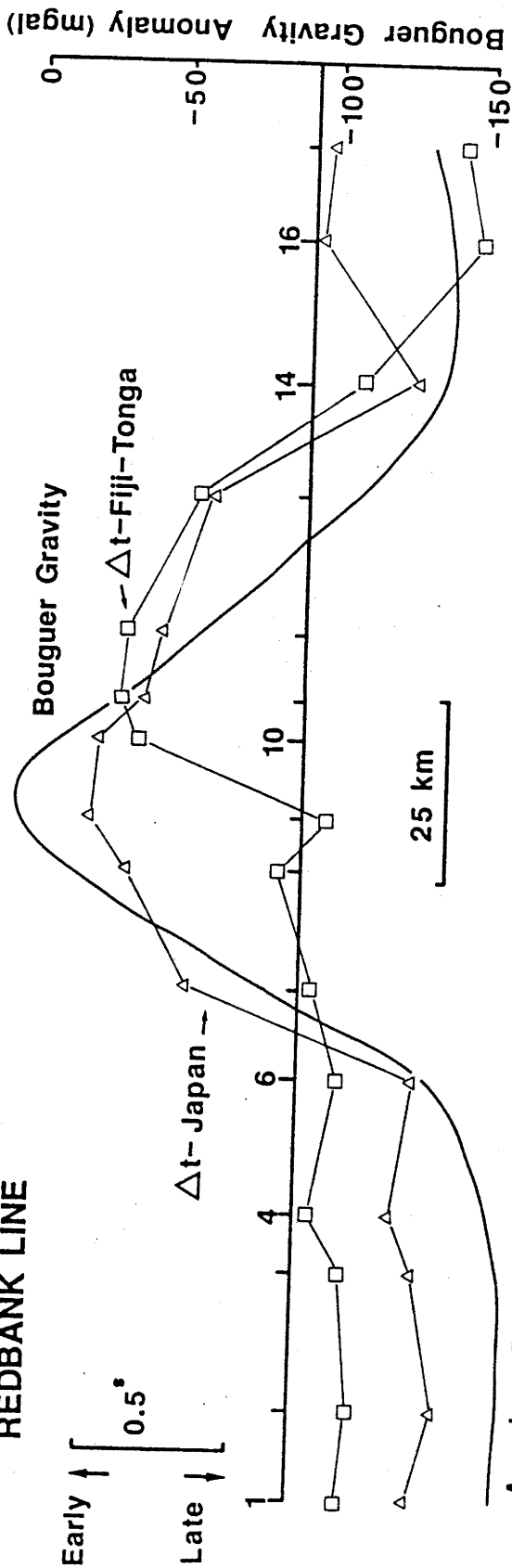
0 300 km
Contour interval 100 $\mu\text{m.s}^{-2}$

11/NT/3-1

Figure 2-3 Geological cross-sections for the Arunta line (Section 3, located in Figure 2-1), showing gravity and teleseismic residual profiles. See Figure 2-4 and Table 2-1 for rock type legend.

Figure 2-4 Geological cross-sections for the Redbank line (Section 4, located in Figure 2-1), showing gravity and teleseismic residual profiles. See Figure 2-4 and Table 2-1 for rock type legend.

REDBANK LINE



Unit	Density g cm^{-3}	Velocity km s^{-1}
1	2.64	4.8
2	2.71	6.5
3	2.68	6.4
4	2.72	6.5
5	2.81	6.7
6	2.73	6.5
7	2.95	7.0
8	2.73	6.5
9	2.72	6.5

Figure 2-5 Geological cross-section for the Ellery line (Section 5, located in Figure 2-1), showing gravity and magnetic profiles. See Figure 2-4 and Table 2-1 for rock type legend.

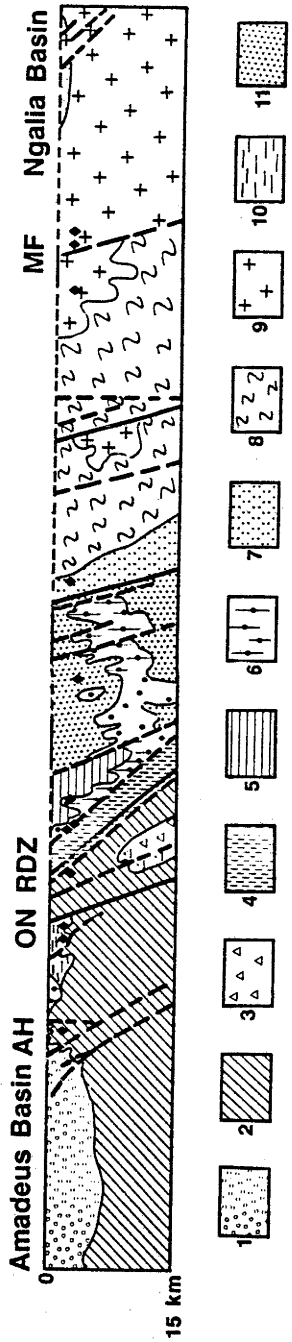
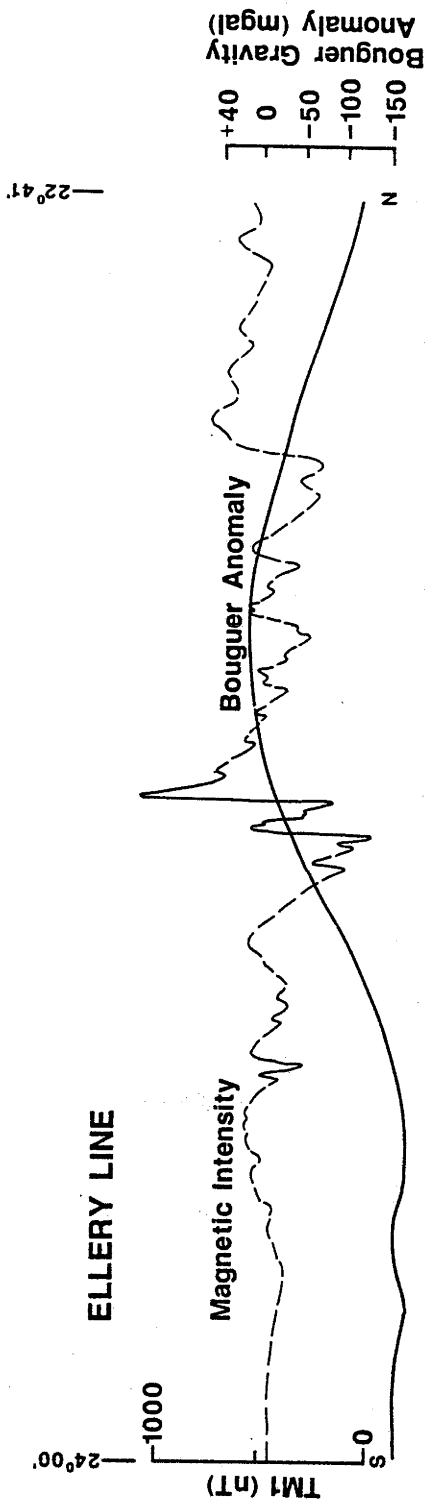


Figure 2-6 Geological interpretation of S–N seismic section across the northern margin of the Amadeus Basin. Section extends from Waterhouse Range to the Amadeus Homocline near Hugh River (see below) and shows the inferred onlap of the units of the Pertnjara Group.

The interpreted picks for seismic reflectors are:

1. Base of Undandita Member of Brewer Conglomerate
2. Unit within Brewer Conglomerate
3. Base of Ljiltera Member at the Amadeus Homocline
4. Base of Brewer Conglomerate
5. Unit near the top of the Pacoota Sandstone
6. Cambrian carbonates within Goyder Formation
7. Unit near the top of the Arumbera Sandstone
8. Detachment horizon within the Bitter Springs Formation

Geological features specified are:

(L) = Northern limit of Ljiltera Member

(M) = Northern limit of Mereenie Sandstone

M = Mereenie Sandstone

H = Base of Heavitree Quartzite

F = Exposed fault

Depths are calculated for stacking velocities at SP5 and SP19. Stacking velocities at SP19 are extrapolated to SP29. Extrapolation to the surface is controlled by horizon 6 which is the most distinctive horizon in the basin.

Geological boundary = dashed line — — — —

Inferred boundary = short dashed line -----

The section extends from 24°00'N, 133°26.4'E (S) to 23°55.8'N, 133°25.6'E(X) to 23°47'N, 133°27.0'E(N). The section line in line 3-3N, migrated by Pancontinental Petroleum, 1983.

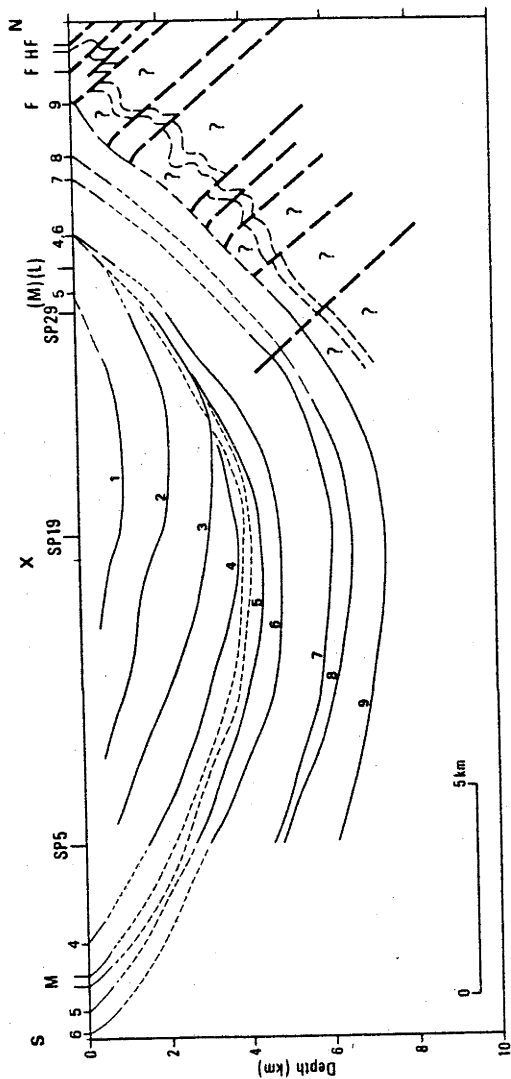
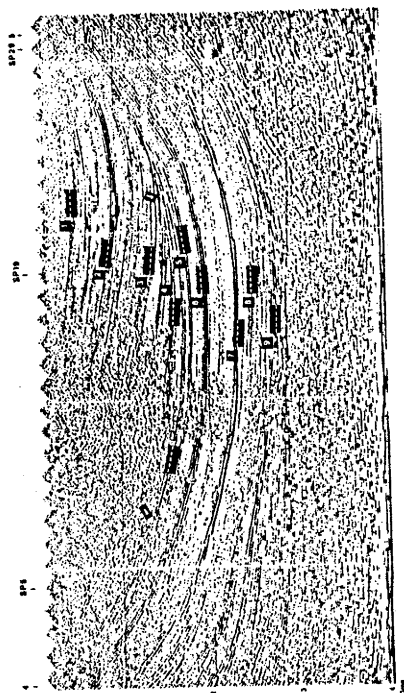


Figure 2-7 Map showing the distribution of metamorphic facies in the region of the Redbank Deformed Zone (RDZ) and the location of samples used in PT determinations listed in Table 3-8. The map also shows the relationship of Rb-Sr biotite ages to the RDZ and to the metamorphic facies.

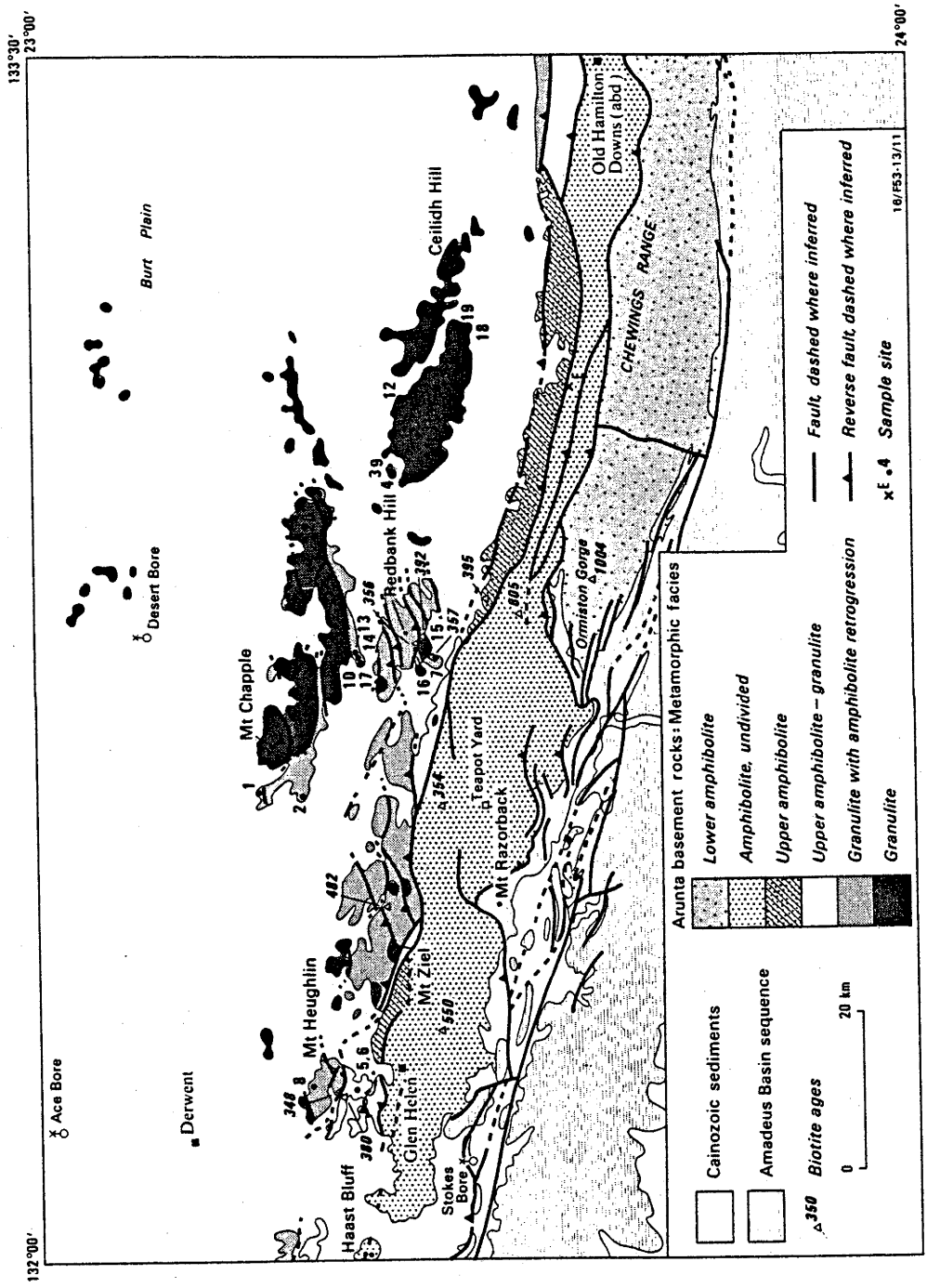


Figure 2-8 The relationship between grain density and chemical composition expressed as weight % SiO_2 for basement rocks.

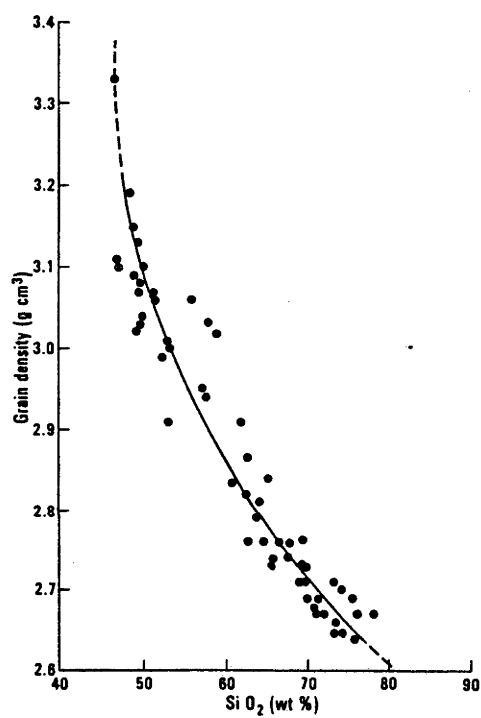


Figure 2-9 Ground scintillometer value (c/s) as a function of wet density (Mg m^{-3}) for basement rocks.

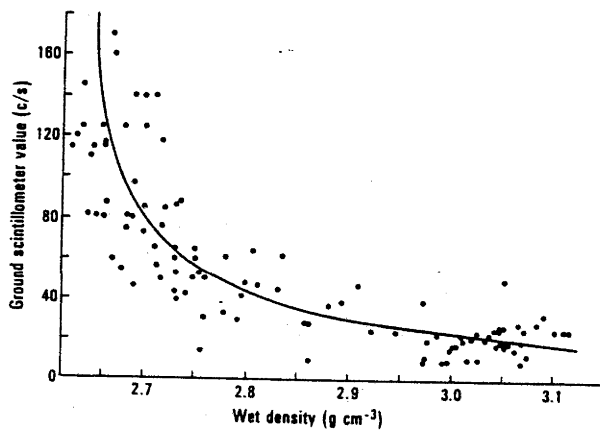


Figure 2-10 Empirical relationship between averaged ground scintillometer value (c/s) and total airborne radiometric count for each tectonic block.

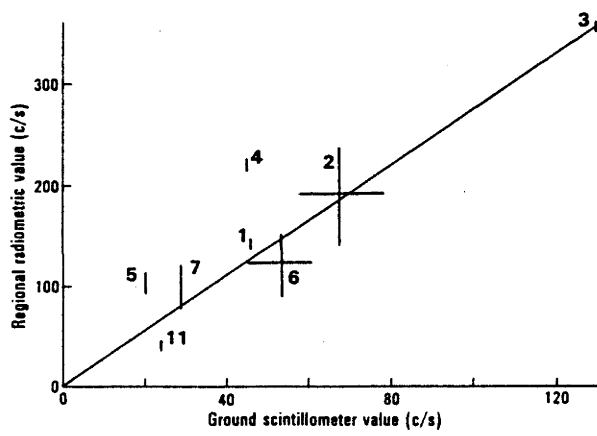


Figure 2-11 Relationship between acoustic velocity and grain density for measured laboratory samples. The linear extrapolation is that of Christensen and Fountain (1975).

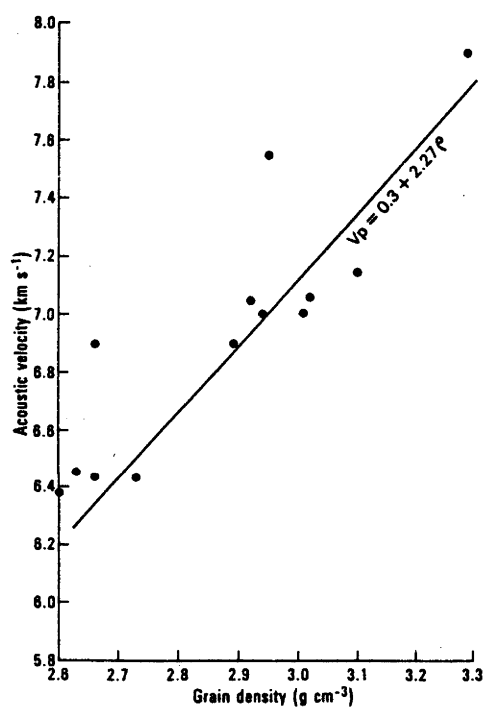
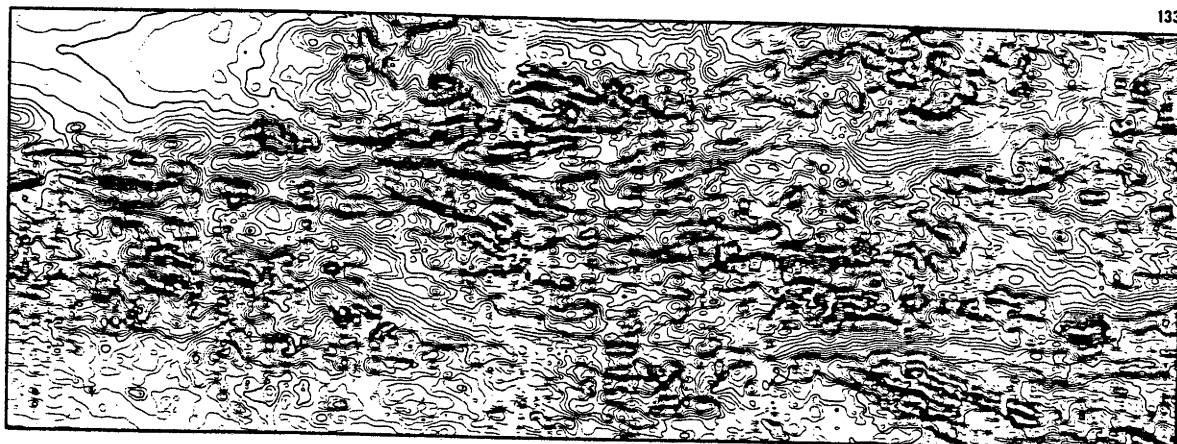


Figure 2-12 Total magnetic intensity map for the basement region [northern part of the Hermannsburg 1:250 00 Sheet area, see BMR (in prepa.) for more details] and interpreted distribution of faults. See Figure 2-13 and Mutton & Shaw (1979) for modeling of magnetic gradients as high-angle faults and the interpretation of these faults as reverse faults.

132°00'



133°30'
23°00'

23°30'

132°00'



133°30'
23°00'

23°30'

----- Fault, inferred from magnetic signature
——▲—— High-angle fault, inferred from magnetic signature

0 20 40 km

Figure 2-13 Modeled aeromagnetic signal for high-angle faults separating blocks with contrasting magnetic susceptibilities.

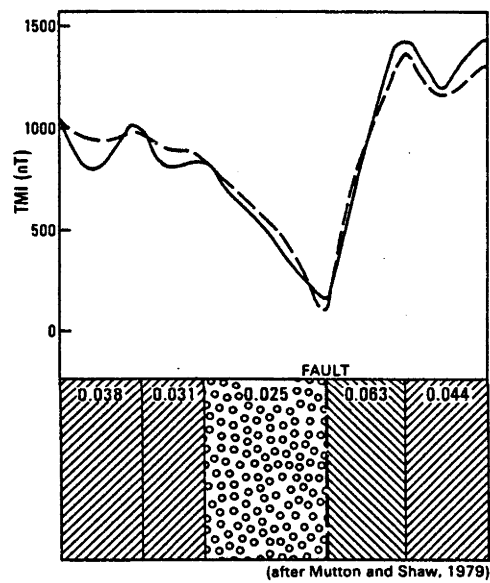


Figure 2-14 Gravity model along Longitude 133° E across the Arunta Block, Amadeus Basin and Musgrave block. (see Figure 2-1 for location).

LONGITUDE 133° 00' LATITUDE 22°S-28°S

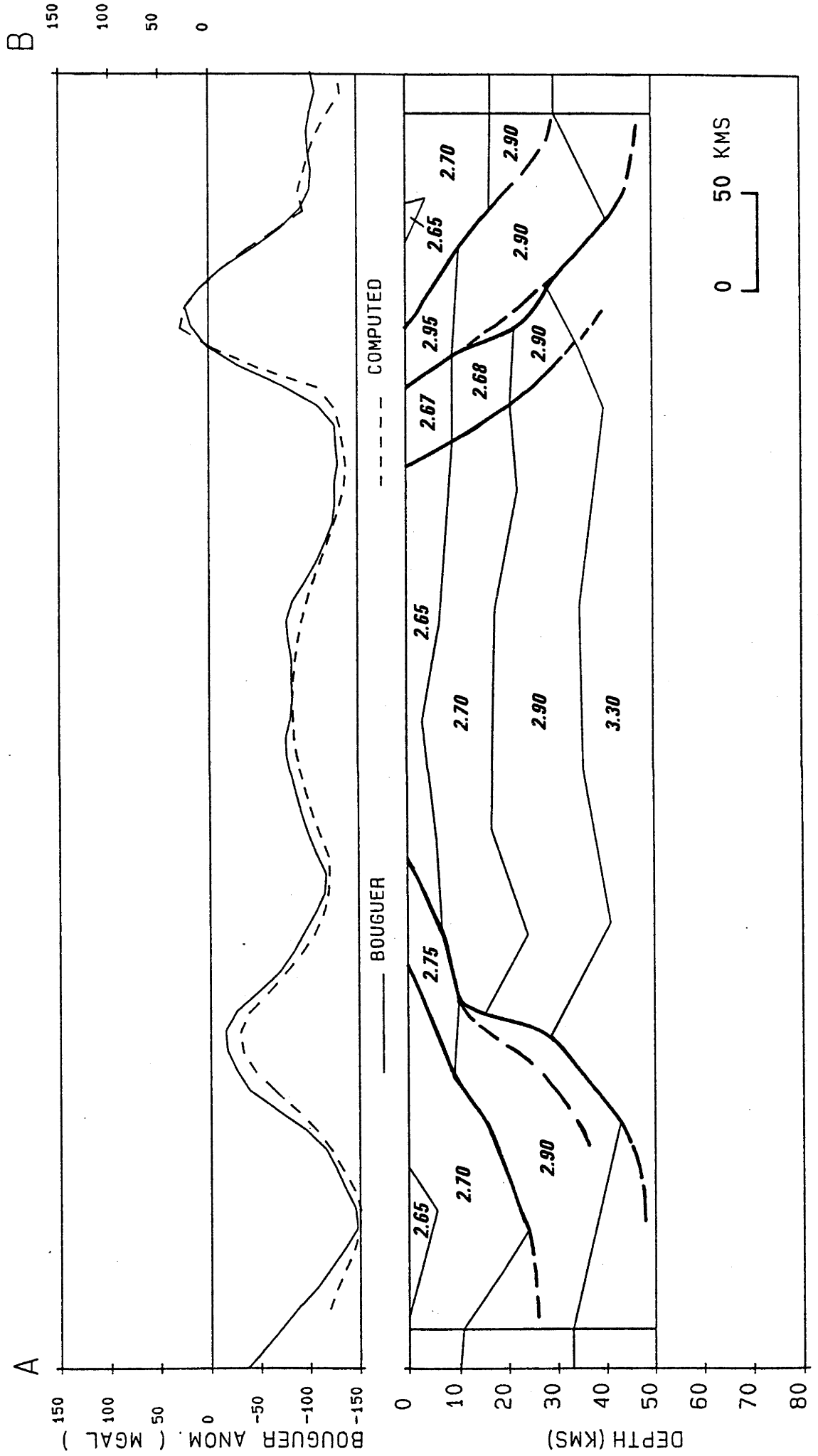
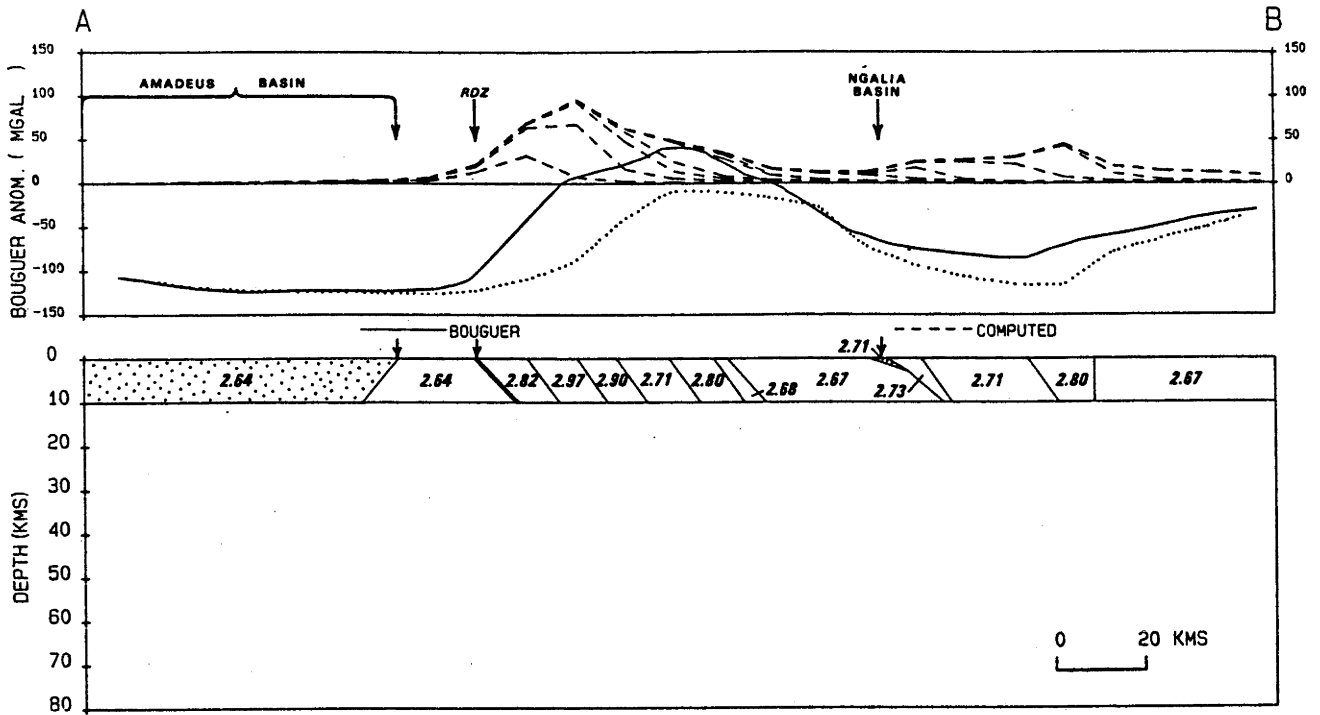


Figure 2-15 Oblique gravity model across the southern Arunta Block. (see Figure 2-1 for location).

- Calculated gravity for each body
- _____ Observed gravity
- Residual gravity

OBLIQUE PROFILE REDBANK ZONE



OBLIQUE PROFILE TO 20 KM DEPTH

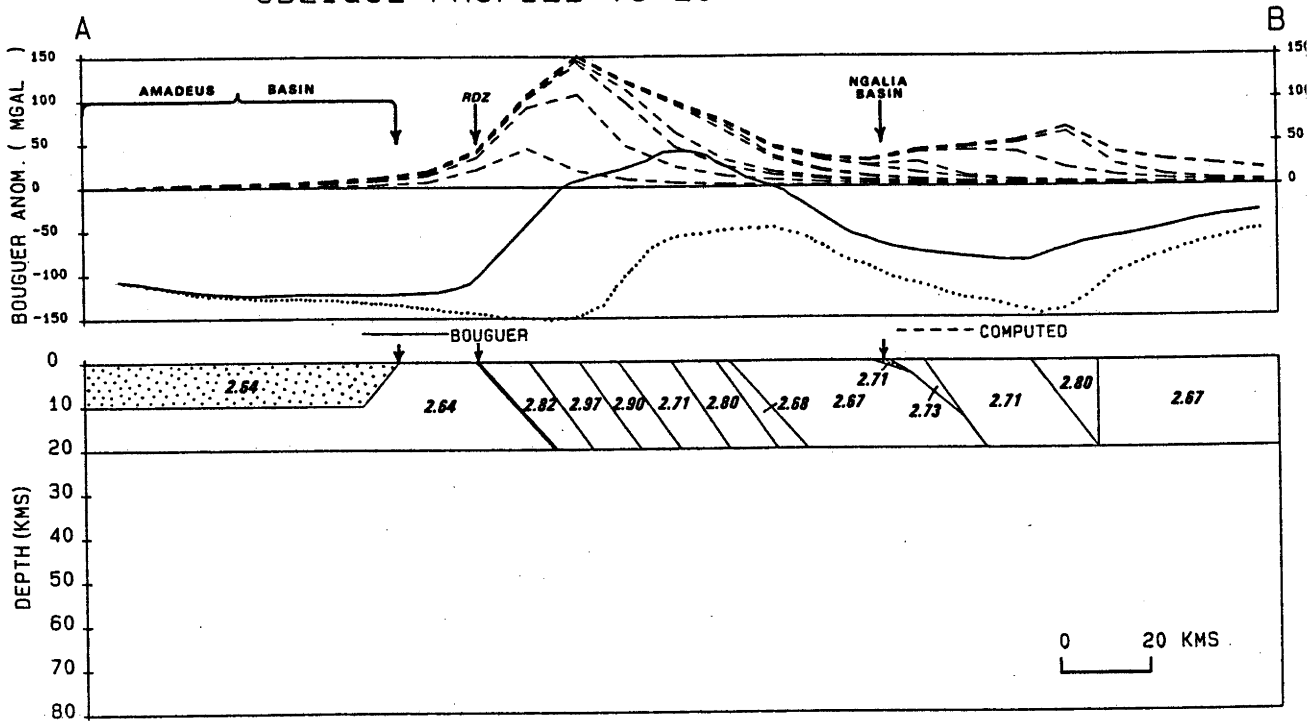


Figure 2-16 Gravity models along the Arunta line corresponding to teleseismic residual models 1 and 3.

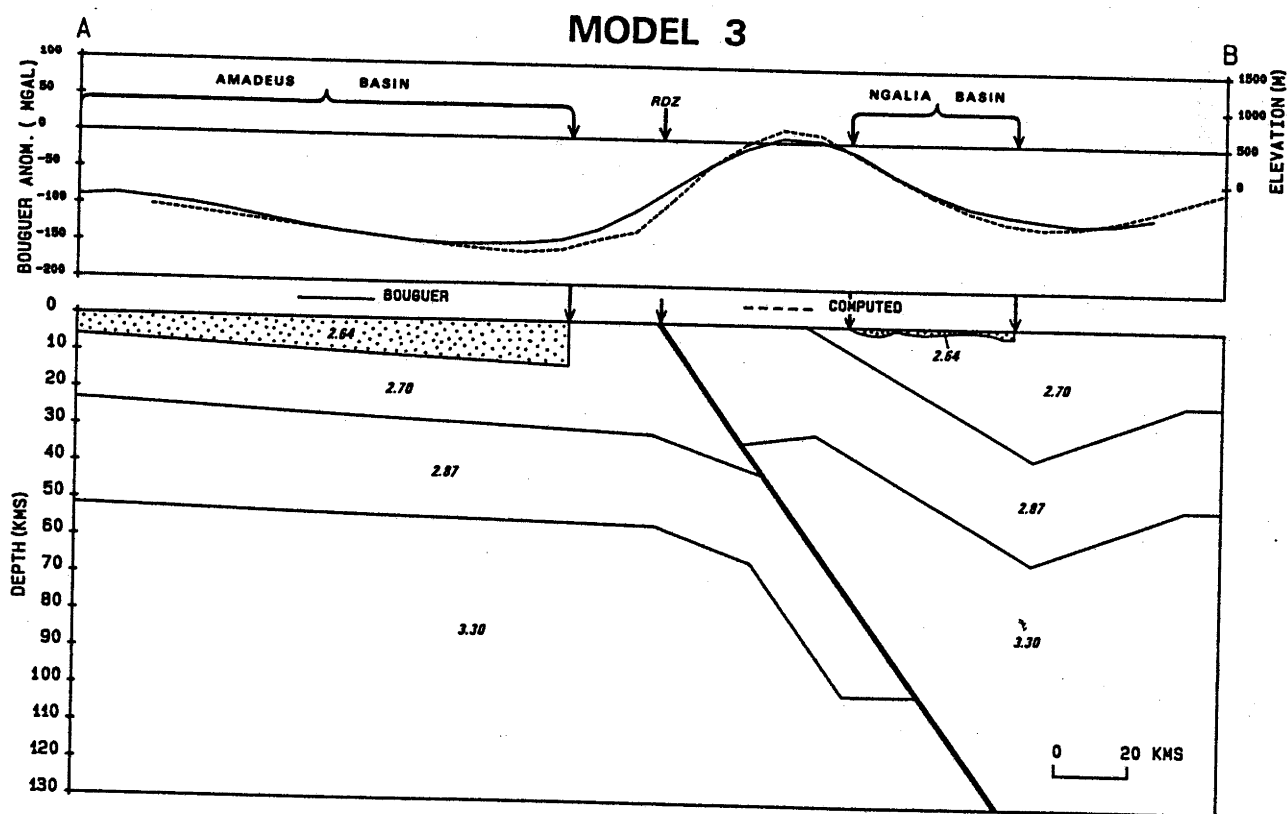
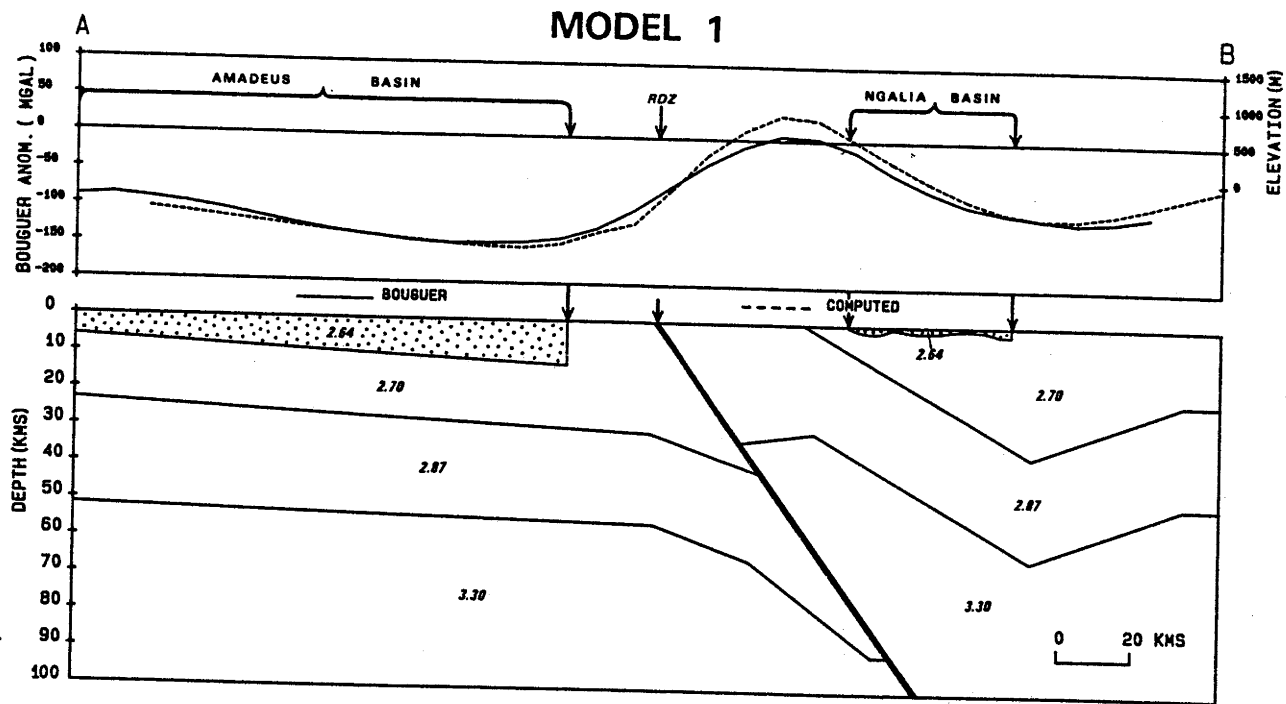


Figure 2-17 Ray tracing for crustal models 1-4 for the Fiji-Tonga events, inferred from the travel time residuals, as reported by Lambeck et al. (1988).

Tonga

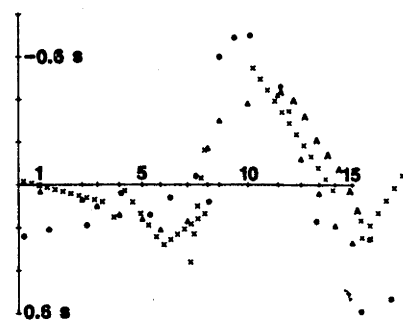
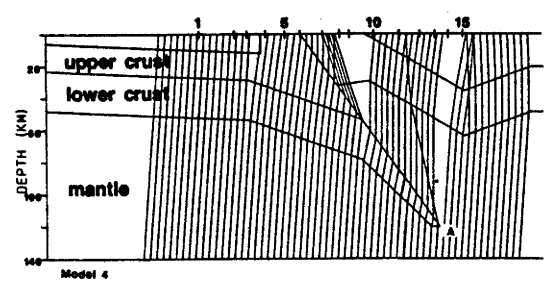
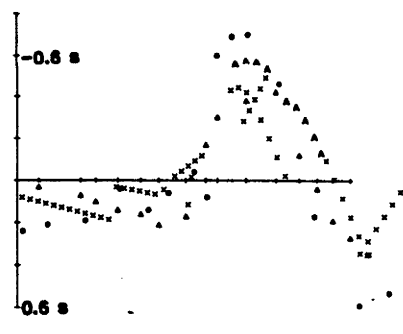
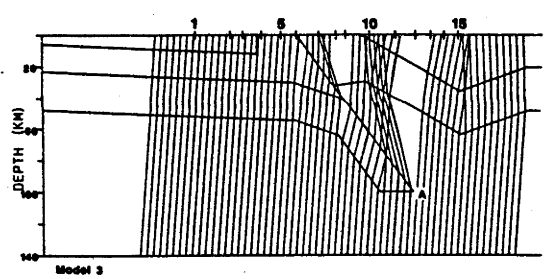
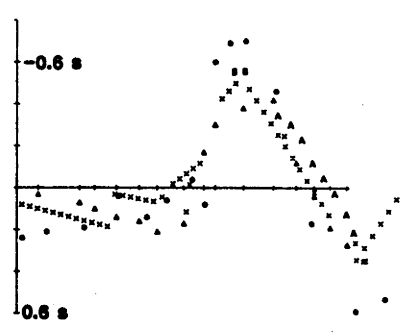
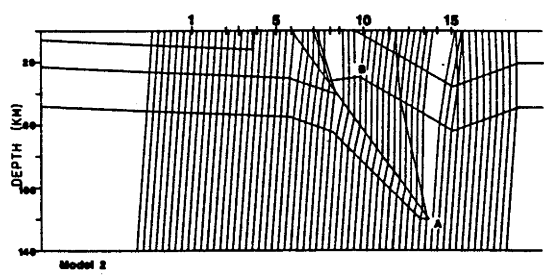
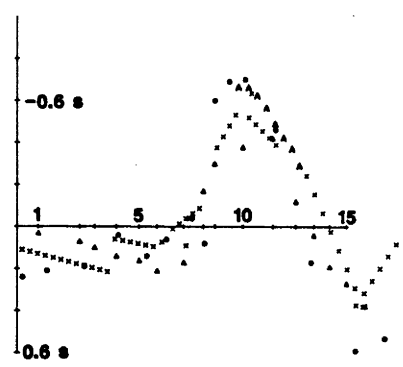
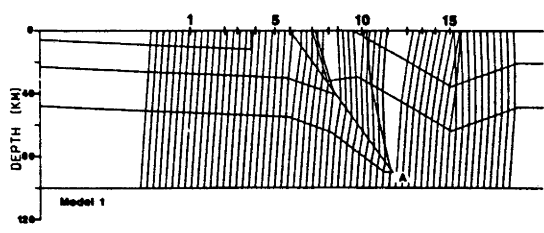


Figure 2-18 Ray tracing for crustal models 1-4, as above, for the Japan-Mariana events.

Japan

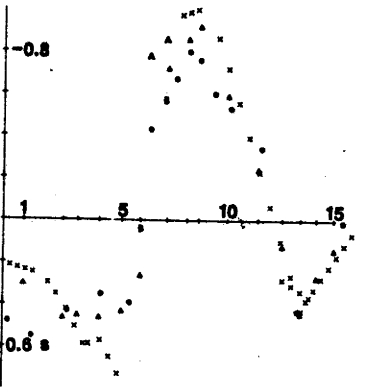
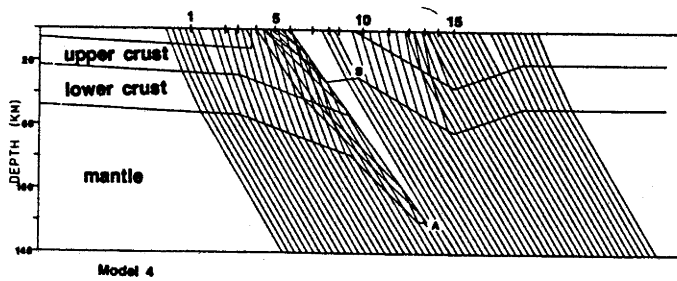
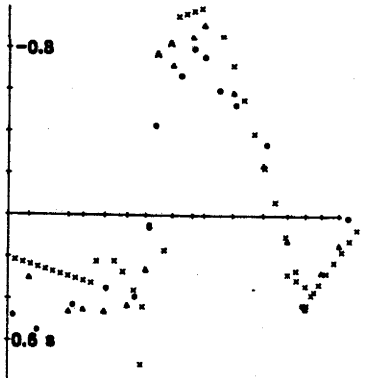
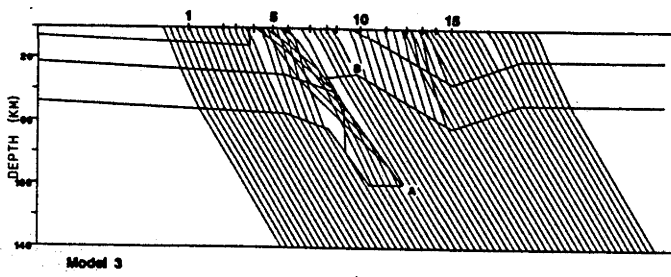
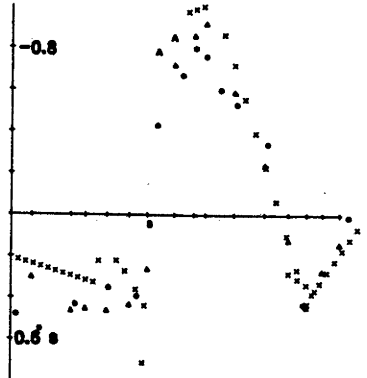
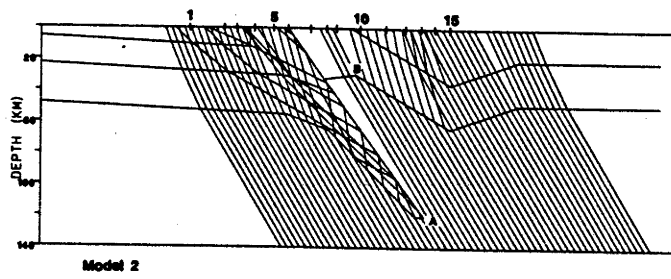
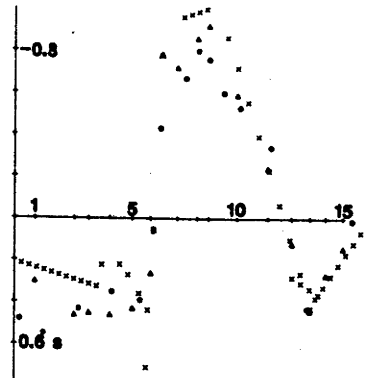
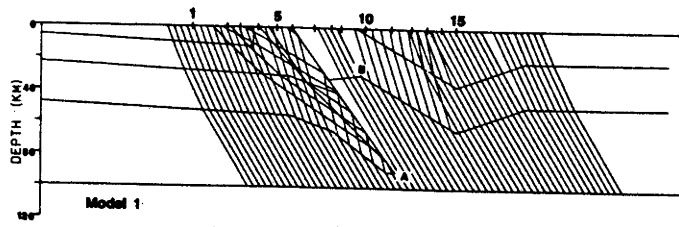


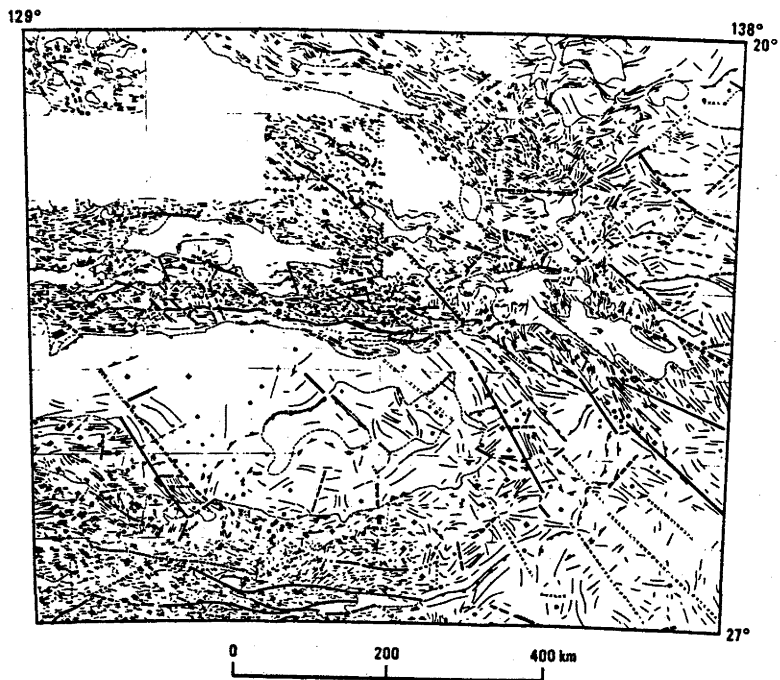
Figure 2-19a The regional distribution of linear gravity features in central Australia. An outline of the basement areas is also shown.

A. Angus Gravity Lineament

E. Ennugan Gravity Lineament

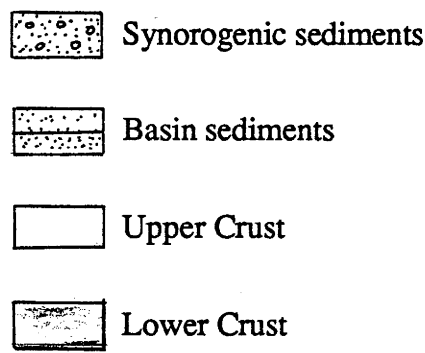
W. Woolanga Gravity Lineament

Figure 2-19b The regional distribution of linear magnetic features in central Australia.

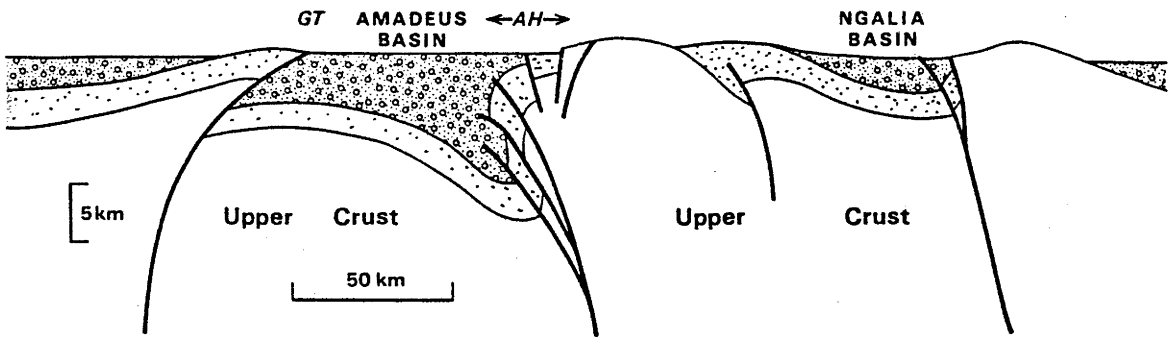


-  Magnetic trend lines
-  Positive 'bulls-eye' anomaly
-  Complex, or regional, equidimensional positive anomaly
-  Minor equidimensional negative anomaly
-  Complex, or regional, equidimensional anomaly
-  Boundary between disturbed and featureless magnetic zones
-  Marked gradient
-  Diffuse or less linear gradient
-  Discordance, well-defined
-  Discordance, moderately well-defined
-  Discordance, poorly-defined
-  Discordance, questionable
-  Discordance, abrupt changes in amplitude along strike
-  Discordance, as above, diffuse
-  Discordance, cross-cutting trough

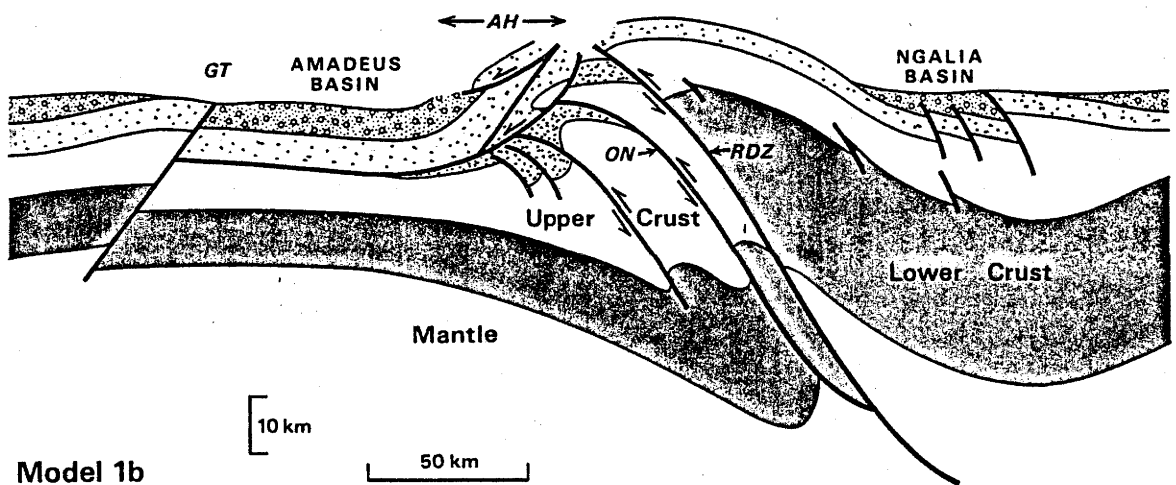
Figure 2-20 Tectonic models for the crustal section between the Amadeus and Ngalia basins.



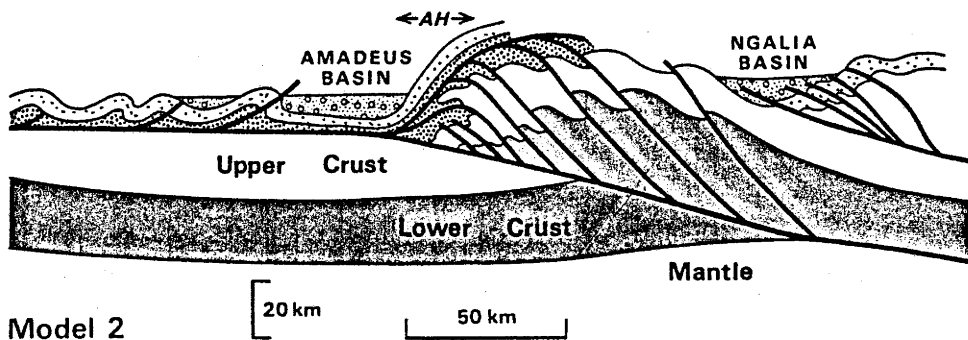
TECTONIC MODELS



Model 1a



Model 1b



Model 2

CHAPTER 3

STRUCTURE AND UPLIFT HISTORY OF THE BASEMENT

Figure 3-1 Map of Arunta Block showing principal structural features and tectonic provinces. RDZ = Redbank Deformed Zone, ANC = Arltunga Nappe Complex, BN = Blatherskite Nappe, DZ = Delny-Mount Sainthill Fault Zone, HZ = Harry Creek Deformed Zone, IZ = Illogwa Creek Schist Zone, LF = Lander Fault, N = N'Dahla Nappe, O = Olympic Nappe, OFZ = Oolera Fault Zone, RN = Razorback Nappe, SZ = Southern Cross Schist Zone, T = Todd River Nappe, WFZ = Walabanba Fault Zone, WL = Woolanga Lineament.

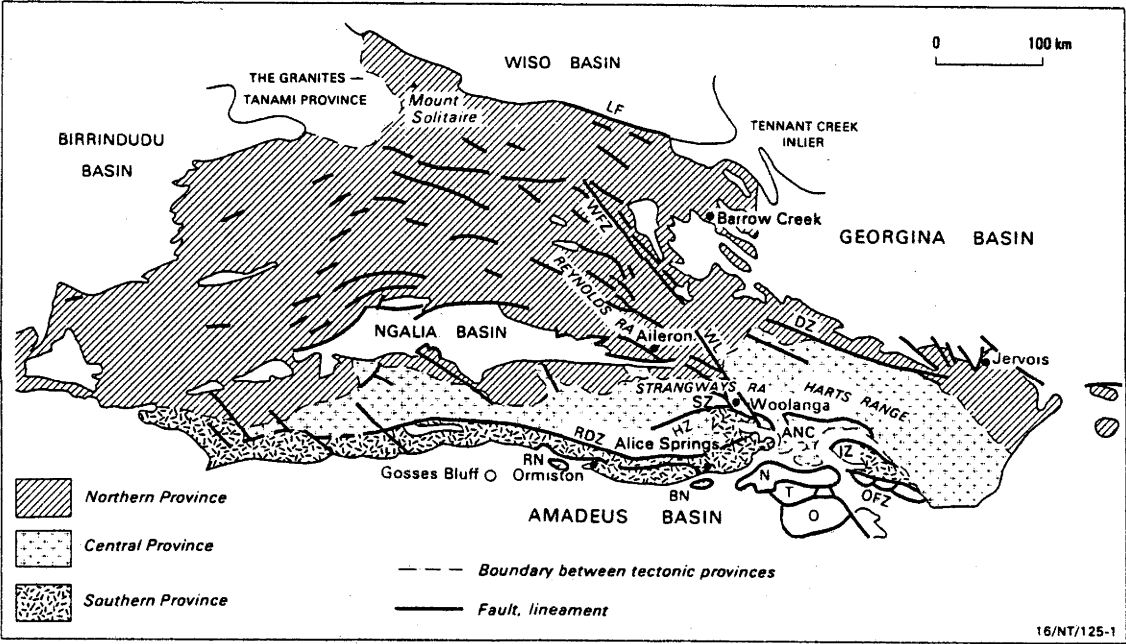


Figure 3-2 Map showing the distribution of principal rock types either side of the Redbank Deformed Zone (RDZ). Also shown are dip variations for 1) older gneissic foliations, 2) the older Type 1 mylonitic foliation and 3) the younger Type 2 phyllonitic mylonite foliation. Rb-Sr age determination sites are also shown (large dots).

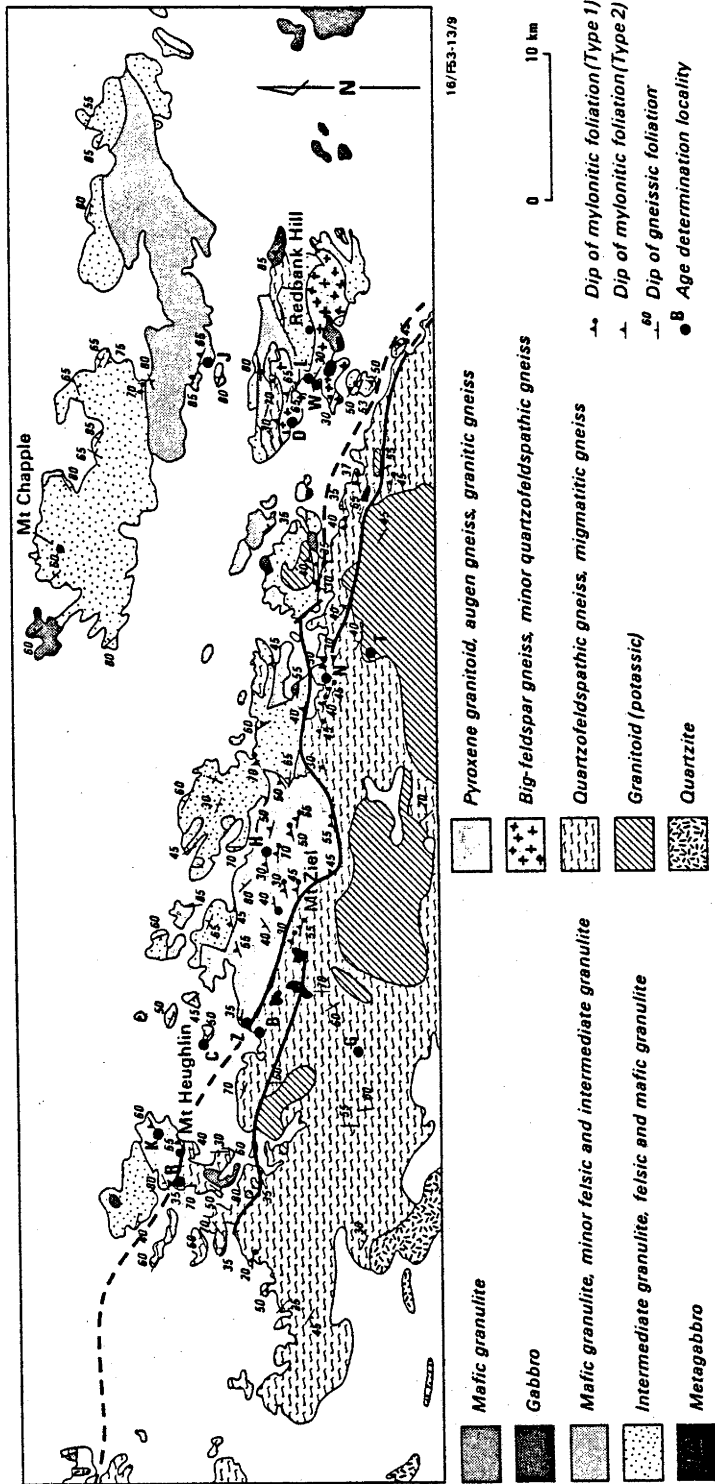
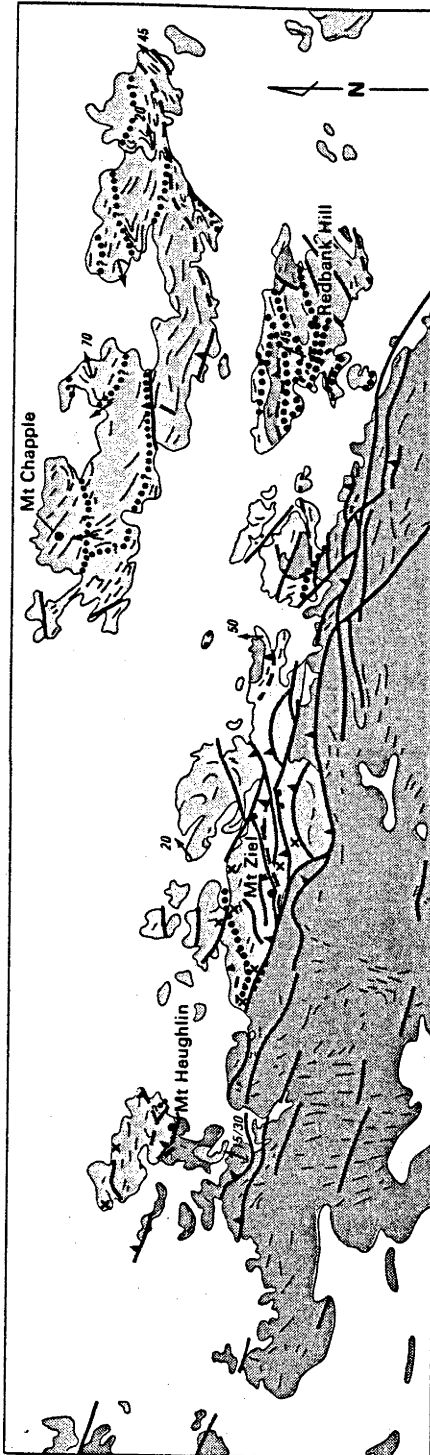


Figure 3-3 Map showing the distribution of older Type 1 and younger Type 2 mylonites in the Redbank Deformed Zone (RDZ). More highly strained, fine grained, Type 1 mylonites are separated from less strained, coarser grained varieties. Foliation trends are $S_0^N=S_1^N$ in the northern granulite facies terrane and $S_0^S=S_1^S$ in the southern amphibolite facies terrane. Amphibolite facies segments shown north of the master RDZ fault zone have undergone retrograde metamorphism and migmatisation, presumably during the Ormiston tectonothermal event (see text).



18/F53-13/10

-- Type 1 ductile deformed zone, coarse grained, showing dip direction

..... Type 1 zone, fine grained

..... Type 1 zone, inferred

--- Type 2 ductile deformed zone

--- Trend of foliation

x Pseudotachylite

→ 45 Plunge of fold

Cainozoic

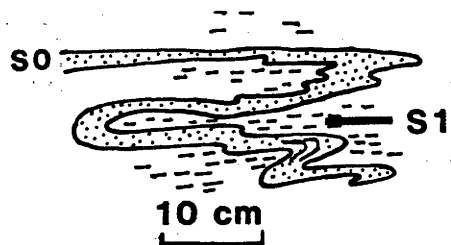
Granulite facies terrain

Amphibolite facies terrain

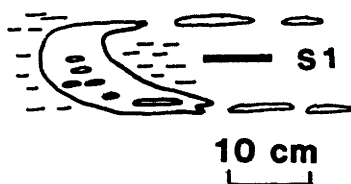
0 10 km

Figure 3-4 F_1 fold styles and overprinting relationships in the northern terrane. The folds are rootless and intrafolial. S_1 is a gneissic schistosity which parallels a transposed compositional layering. a1) F_1 isoclinal folds with sharp hinge regions. A slight layer-parallel foliation in one fold core suggests an earlier phase of folding (Locality NW of Ceilidh Hill; a2) Thickening in the fold hinge (Ceilidh Hill, FP 1781); b1, b2, b3) Similar fold styles of F_1 folds (FPS 1781, 1779, 1780); c and d) Examples of F_1 overprinted by F_2 thin mobilisate layers parallel S_2 ; e) S_2 foliation outlined by oblate quartz aggregates oblique to S_1 transpositional layering outlined by mafic granulite and quartzofeldspathic gneiss (10 km east of Mount Chapple, FP 1736).

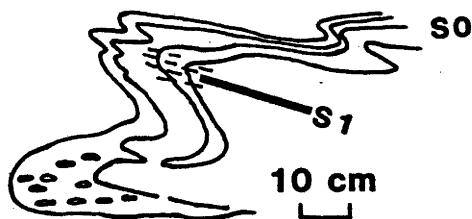
(a1)



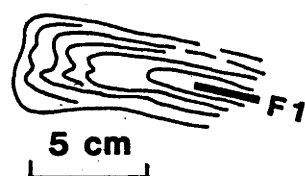
(a2)



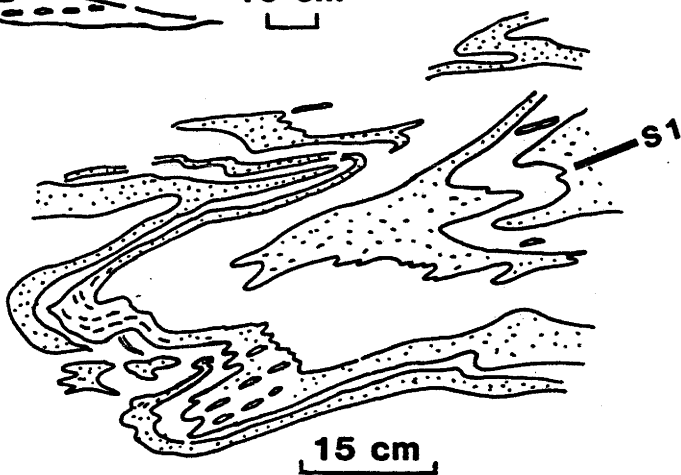
(b1)



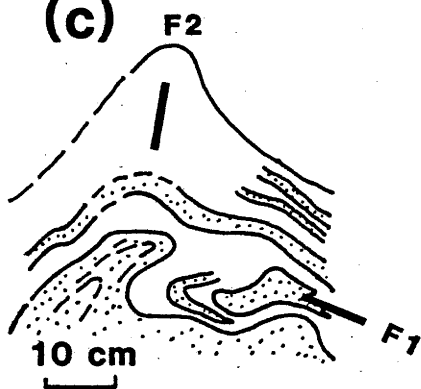
(b2)



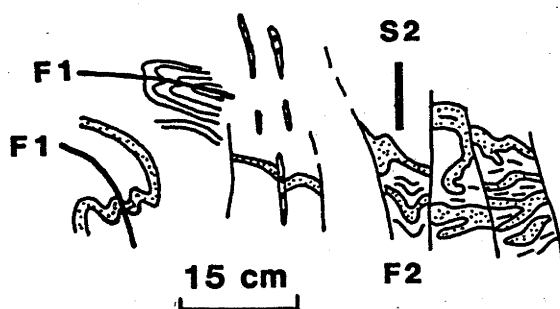
(b3)



(c)



(d)



(e)

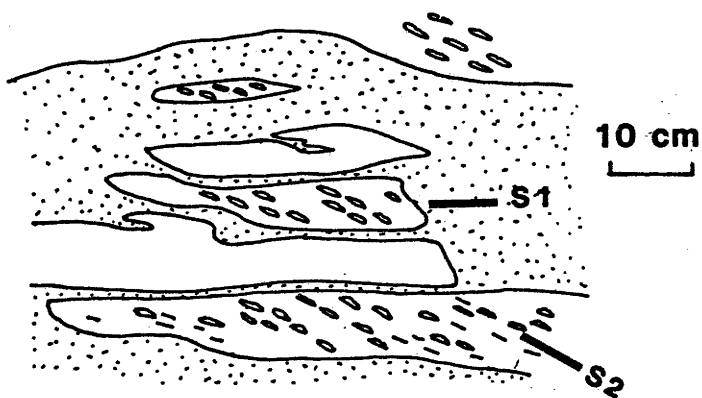
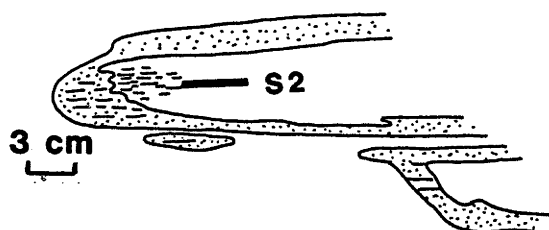
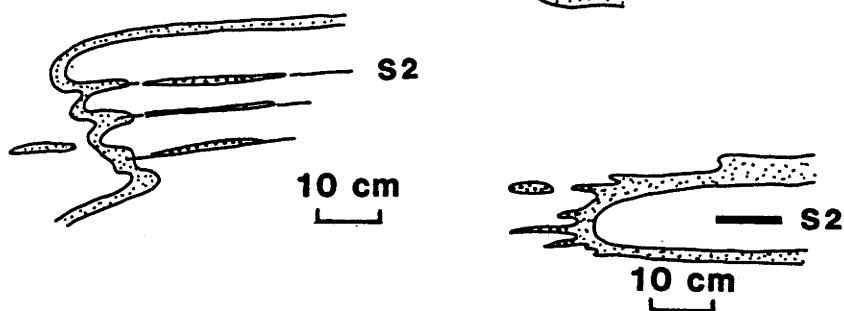


Figure 3-5 F_2 fold styles. F_2 folds are cylindrical, isoclinal and reclined. S_2 forms a gneissic layering or a domainal foliation. Mobilisate layers commonly parallel S_2 . a) Isoclinal F_2 fold with weak S_2 schistosity (FP 1705, 10 km east of Mount Chapple Fig.2-7); b) Thin mobilisate layers parallel S_2 (FP 1705); c) Mobilisate invading S_2 (FP 1706); d) Intercalated mafic granulite and augen gneiss folded by late F_2 (FP 1299, west of Locality D, Fig. 3-2) e) Mobilisate layers parallel S_2 and is also discordant to S_2 (FP 1839-41, 6 km NE Locality 20, Fig. 2-7. i.e. south of Mount Chapple Bore)

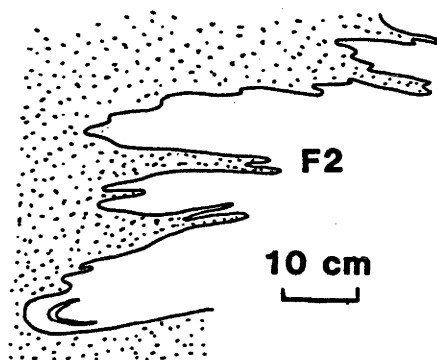
(a)



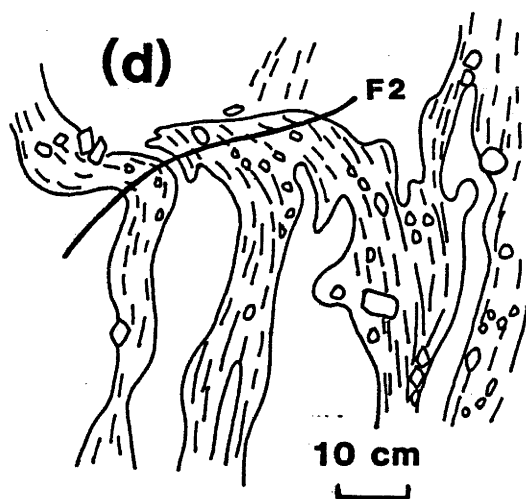
(b)



(c)



(d)



(e)

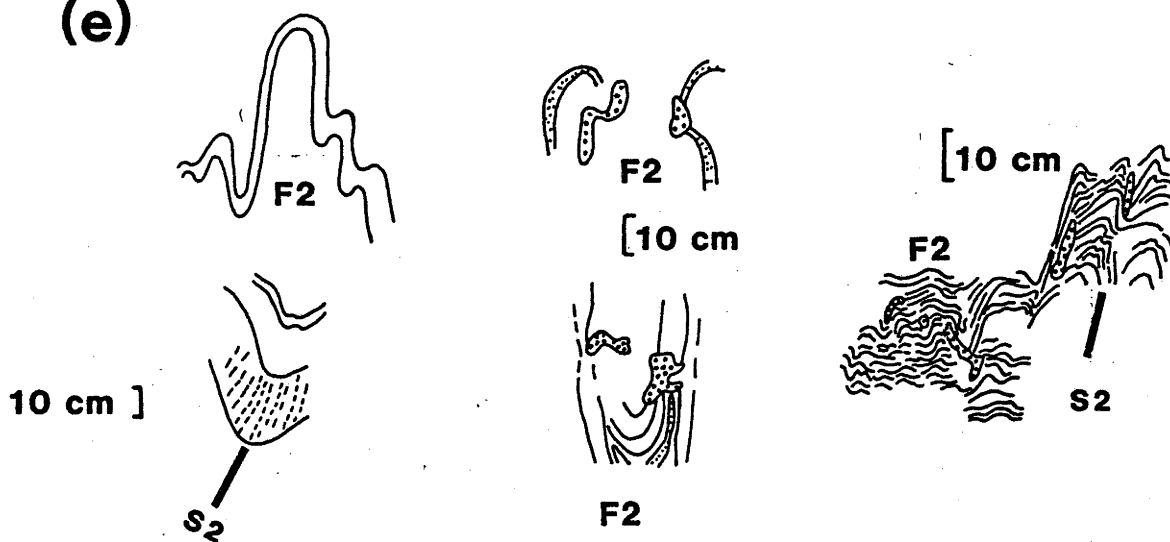


Figure 3-6 Schematic diagram showing structural elements of a macroscopic F_2 fold outlined by mafic granulite and augen gneiss preserved on the southeastern flanks of the Redbank Hill massif. Macroscopic F_2 folds plunge at 45° to 32° , are approximately coaxial with F_1 , and accompany strong prolate regional strains which reach their maximum in the F_2 hinges. A small F_1 fold (plunging 20° to 30° , not shown in Figure) in the hinge of the macroscopic F_2 fold indicates local refolding of F_1 by F_2 . S_1 is strongly developed in the augen gneiss. The composite S_1/S_2 foliation is cut by dykes of mafic granulite. D_1 and D_2 are considered to represent two stages in a continuous progressive deformation. L_2 is an intersection-lineation and as a result D_2 structures are dominated by L and L-S fabrics due to S_1/S_2 overprinting.

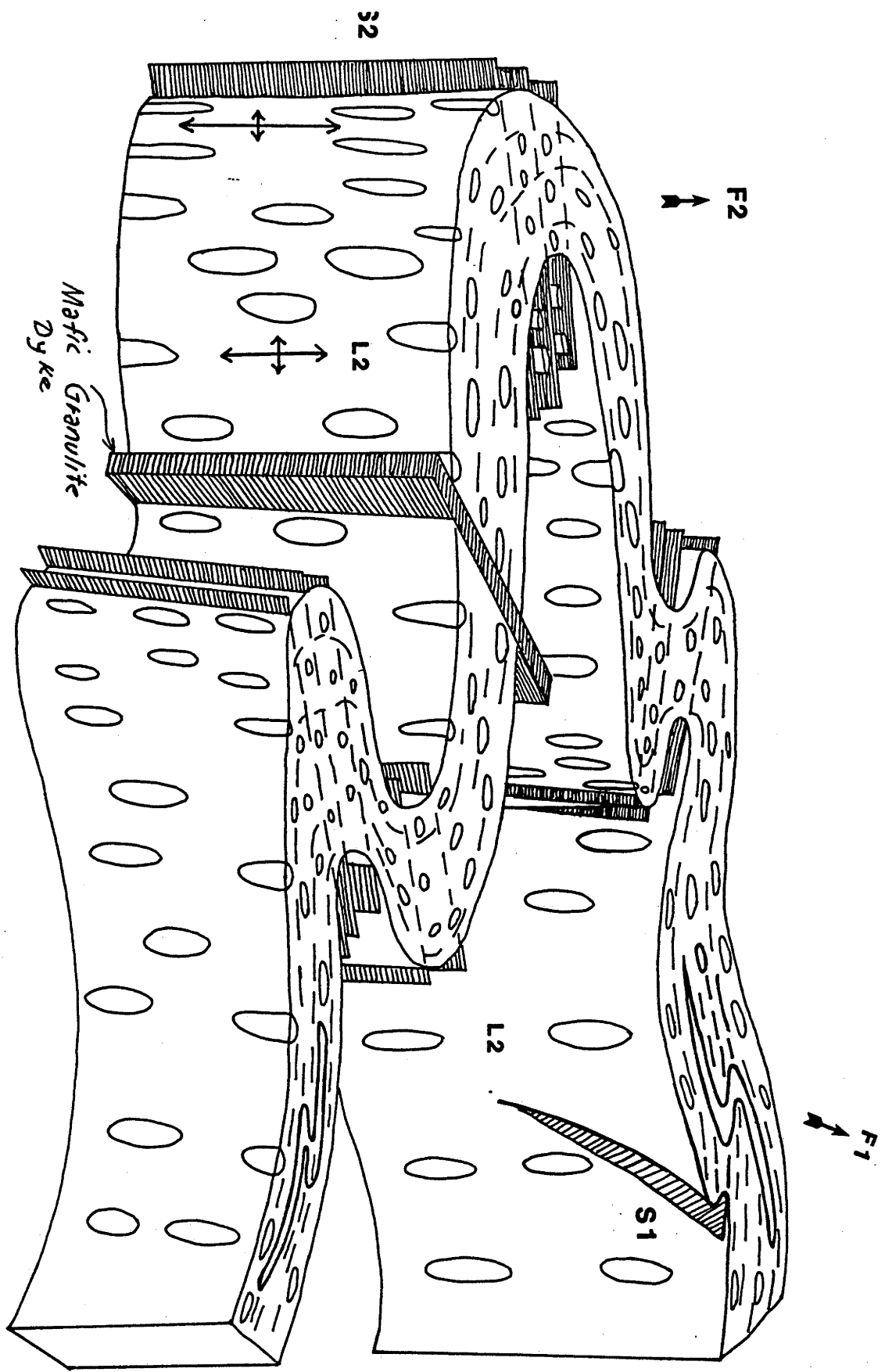
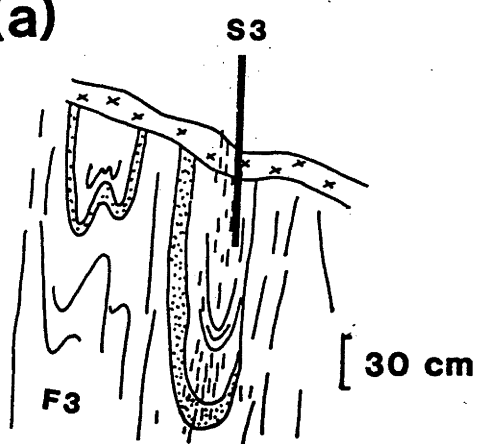
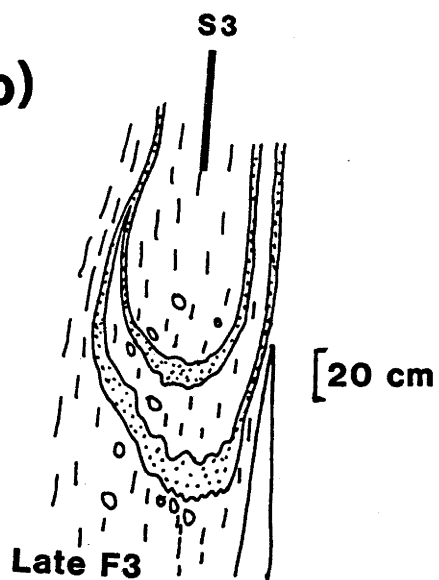


Figure 3-7 F_3 fold styles in the northern terrane. Mesoscopic, tight, upright and isoclinal to sheath-like F_3 folds. S_3 is a strong penetrative foliation. a) Sheath-like folds cut by a pegmatite dyke (Locality H, Fig. 3-2, FP 1636); b) Early D_3 mylonite folded by late F_3 fold (Locality D, Fig. 3-2, FP 1299); c) Folds as at (a) above (Locality R, Fig. 3-2, FP 1676); d) As above (Locality H, Fig. 3-2, FP 1627); e) Feldspar augen elongate parallel to L_3 (Locality 13, Fig. 2-7); f) Highly appressed, sheath-like folds with synclinal structures removed by detachment zones (Locality 13, Fig. 2-7, FP 1619)

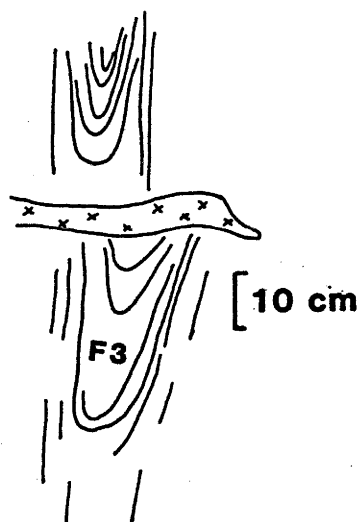
(a)



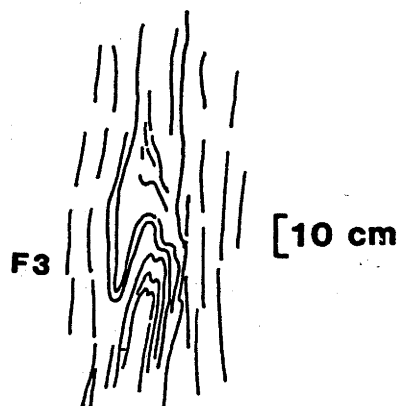
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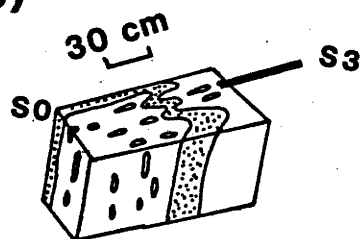
(c)



(d)



(e)



(f)

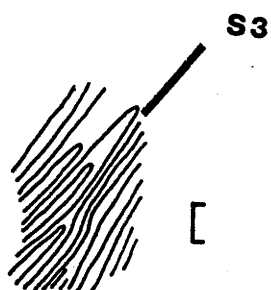
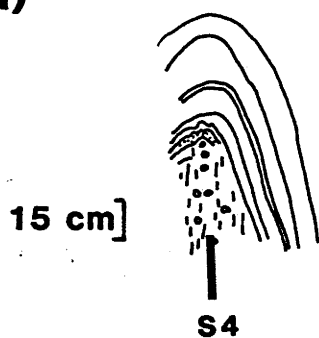
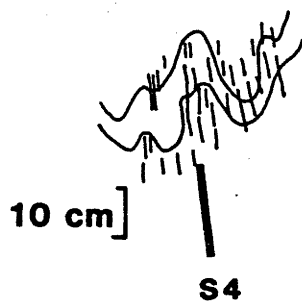


Figure 3-8 F_4 folds in the northern terrane and their relationship to D_5 deformed zones. S_4 locally forms an incipient crenulation cleavage. a) Open, upright, shallowly plunging (23° to the W) F_4 fold with incipient crenulation cleavage (N Locality H, Fig. 3-2 FP 1632); b) Open fold with incipient crenulation cleavage (Locality D, Fig. 3-2 FP 1292), c) Early, variably plunging F_5 folding S_{m5} foliation and cut by later, platy S_{m5} ultramylonite (N Locality H, Fig. 3-2 FP 1634); d) S_{m3} deformed by upright fold ($F_4?$), and cut by D_{m5} deformed zone containing early, disrupted F_5 folds (Locality D, Fig. 3-2 FP 1292, 2121).

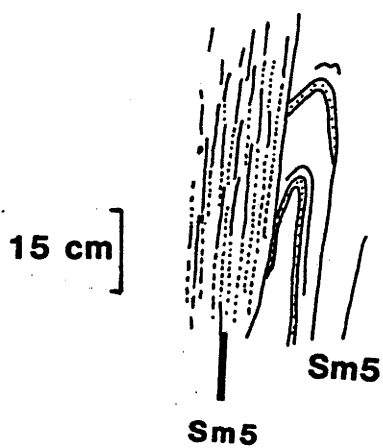
(a)



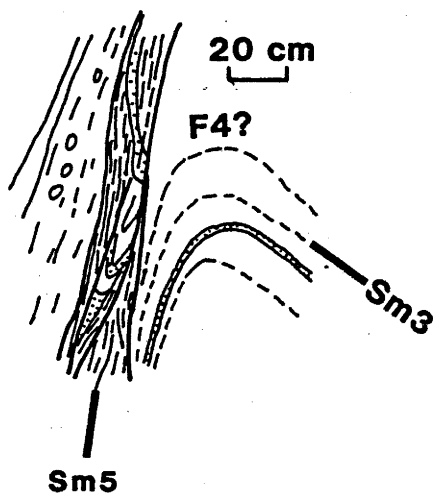
(b)



(c)



(d)



2

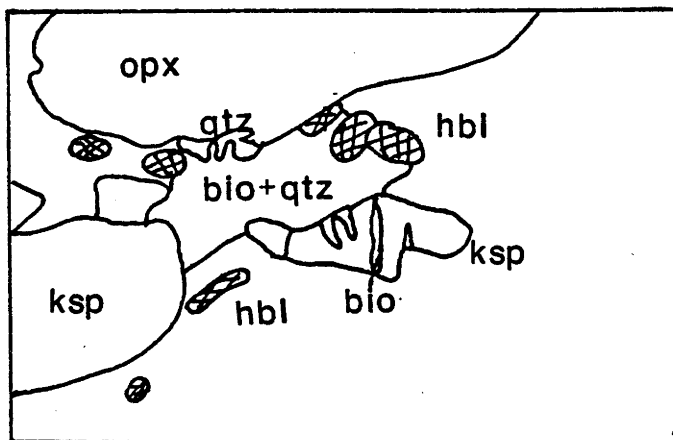


Figure 3-9 Photographs of A) Mylonite types and B) Structural elements (fold styles) in the southern terrane.

A. (Upper half of figure)

1. Type 1 mylonite, locality D (Fig. 3-2), northern (granulite facies) terrane.
2. Breakdown of orthoclase and orthopyroxene to biotite and quartz. Some biotite occupies fractures in orthoclase and hornblende is also present. (TS = 79040015). Locality H (Fig. 3-2), northern (granulite facies) terrane. (Frame width 1.1mm).
3. Contact between Type 2 mylonite (left) and Type 1 mylonite (right). Locality R (Fig.3-2) within the boundary zone between the northern and southern terranes. (Spot is 3.5 cm across).
4. Type 2 mylonite showing a dextral (north over south) sense of shear. Locality B (Fig.3-2), at the boundary between the northern and southern terranes. (matrix grainsize = 40mm)

B (Lower half of figure)

5. Reclined, shallowly south-plunging F_2^S fold in southern terrane. Biro points to late, upright F_3^S fold. Locality is Little Yard, south of Locality E (Fig. 2-7).
6. Aerial view of F_2^S fold outlined by quartzite unit, Chewings Range, southern terrane.
7. Upright, shallowly southeast plunging F_2^S folds with migmatization in axial plane structures, southern terrane, Locality G (Fig. 3-2). (Spot is 3.5 cm across).
8. Mobilisate (D_3^S) penetrating S_2^S foliation, southern terrane. Locality G (Fig. 3-2) (Spot is 3.5 cm across).

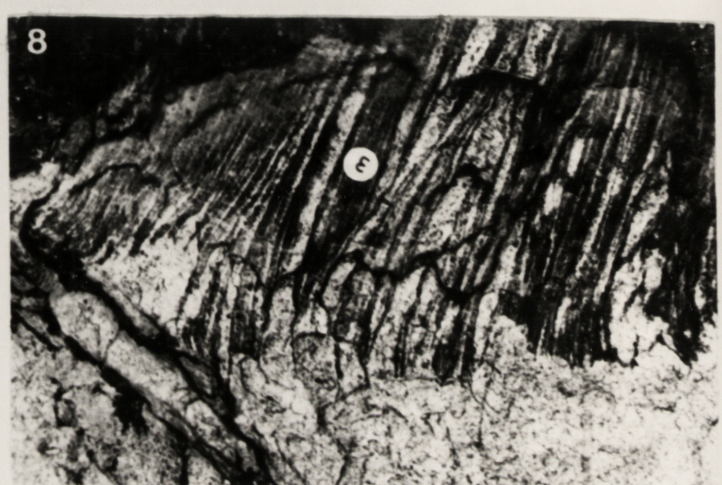
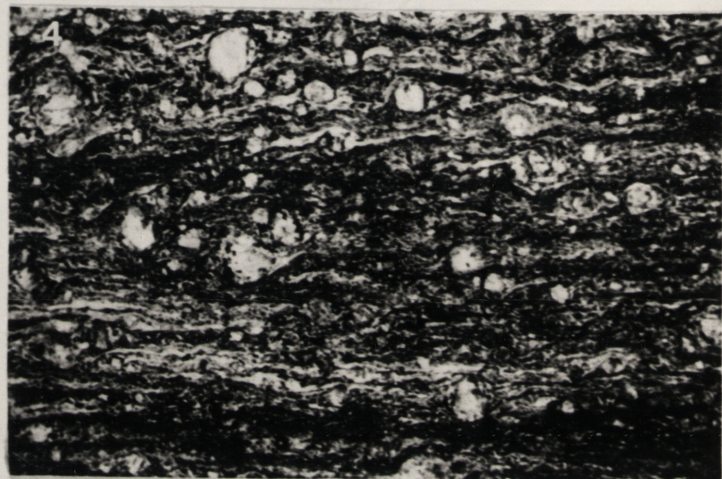
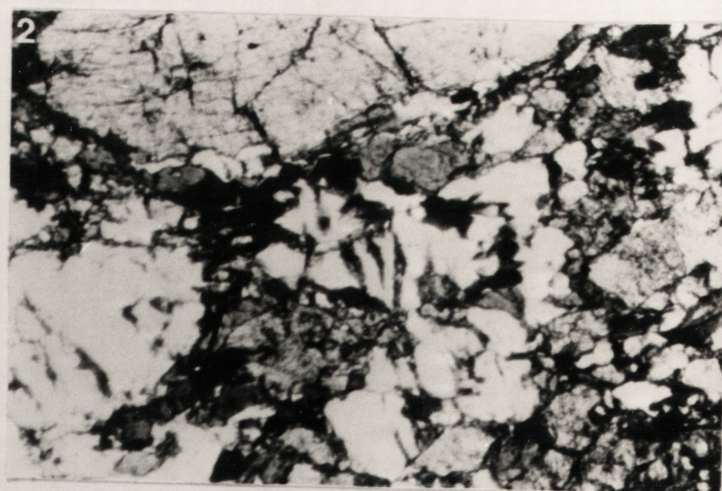


Figure 3-10 Progressive development of Type 1 mylonitic rocks. a) K-feldspar megacrysts (Fs) showing dynamically recrystallized tails. b) Retort-shaped recrystallised tails of K-feldspar megacrysts. c) Spiralling tails on feldspar megacrysts. d) Near spherical K-feldspar megacrysts encompassed by a biotite-rich selvedge. e) Extremely strained rock containing narrow laminae of very finely recrystallised feldspar, granitoid augen and recrystallised quartz ribbons. Relict clasts of granulite are also preserved. f) Advanced mylonitisation in which the matrix grain size is reduced and the size and number of megacrysts is decreased. Relict granulite clasts form thin microboudins or augen which superficially resemble recrystallised feldspar megacrysts. Thus, the feldspar megacrysts are relict clasts.

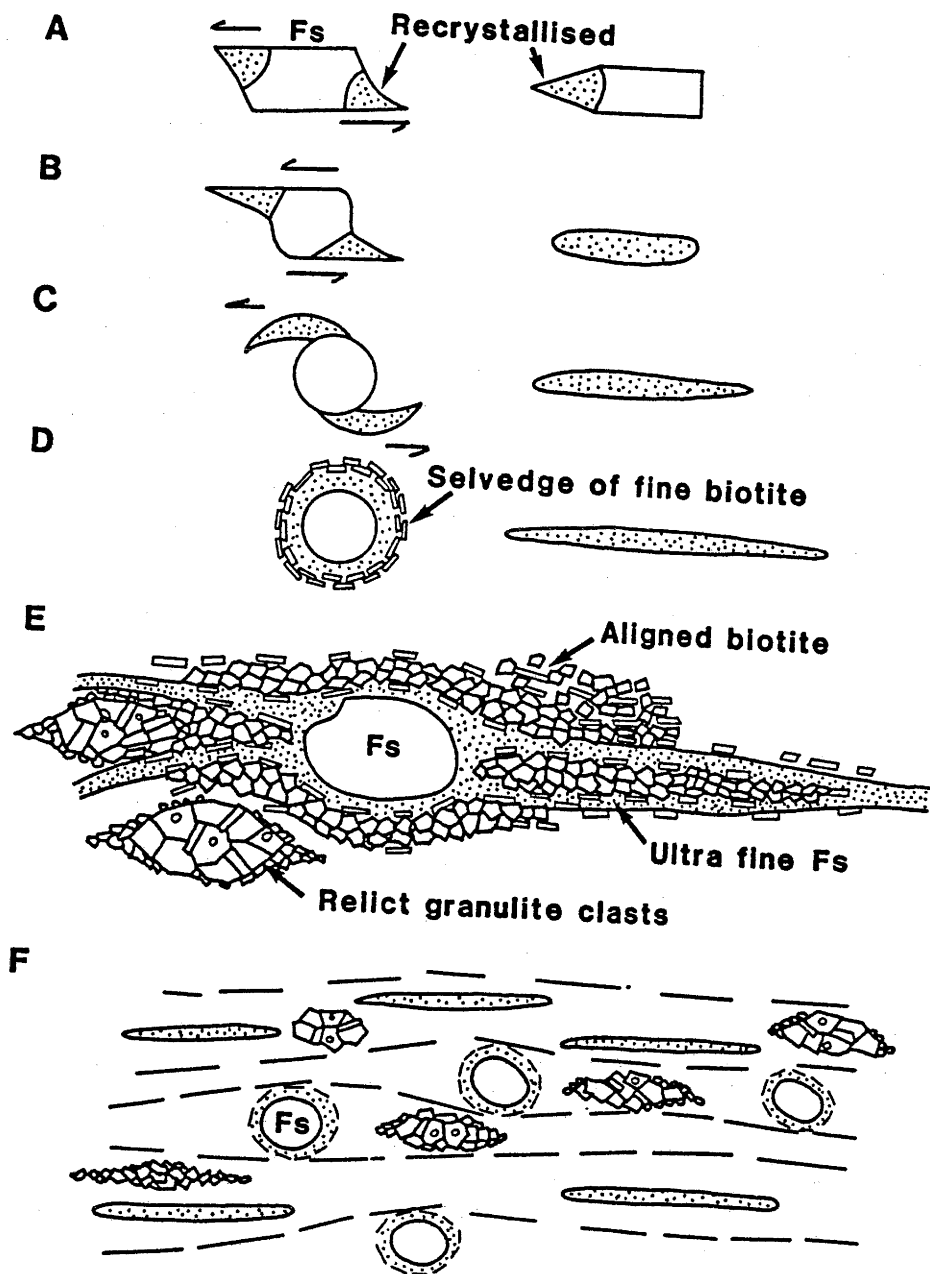
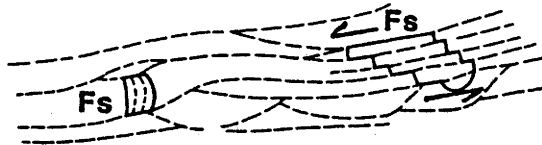


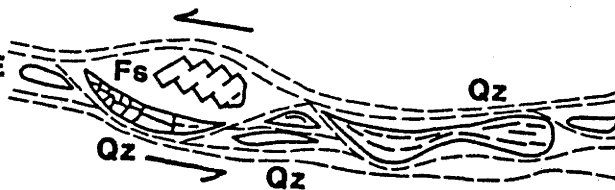
Figure 3-11 Microstructural features of Type 2 mylonite. a) Mylonitic rock. b) Protomylonite. c) "Frilled schist" mylonite. d) Phyllonitic mylonite. e) Phyllonitic ultramylonite. f) Pseudotachylite. The mylonitic foliation is first apparent as a faint, inhomogenously distributed schistosity outline by fine biotite. As the mylonitic schistosity intensifies, it completely overprints earlier foliations and a composite foliation outlined by S and C planes develops (e.g "Frilled schist mylonite"). The mineral constituents are progressively reconstituted during concomitant retrograde metamorphism under greenschist facies conditions to produce phyllonitic ultramylonite. Both quartz and feldspar show evidence of ductile behaviour at this stage (cf Tullis and Yund, 1980).

STAGE
(% matrix)

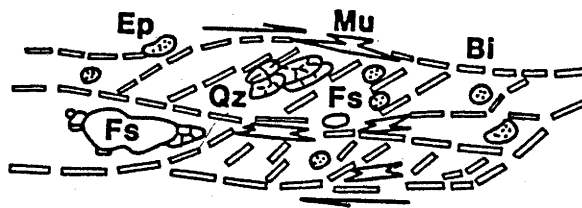
MYLONITIC ROCKS
(0-10)



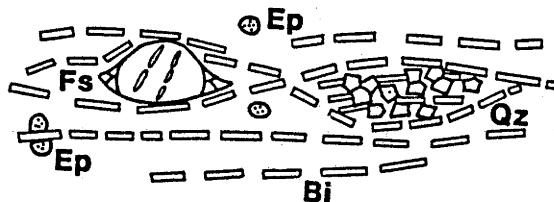
PROTOMYLONITE
(0-50)



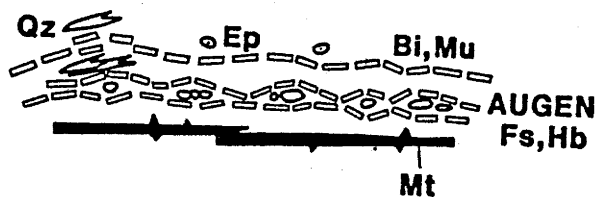
"FRILLED SCHIST
MYLONITE"



PHYLLONITIC
MYLONITE
(50-90)



ULTRAMYLONITE
(> 90)



PSEUDOTACHYLITE

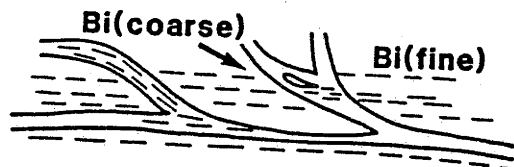


Figure 3-12 Schematic diagram of composite Type 2 mylonite zone formed at the master fault of the RDZ. Pseudotachylite formed in the upper part of the composite deformed zone and also filled fractures in the granitoids in the overlying retrograde granulite terrane.

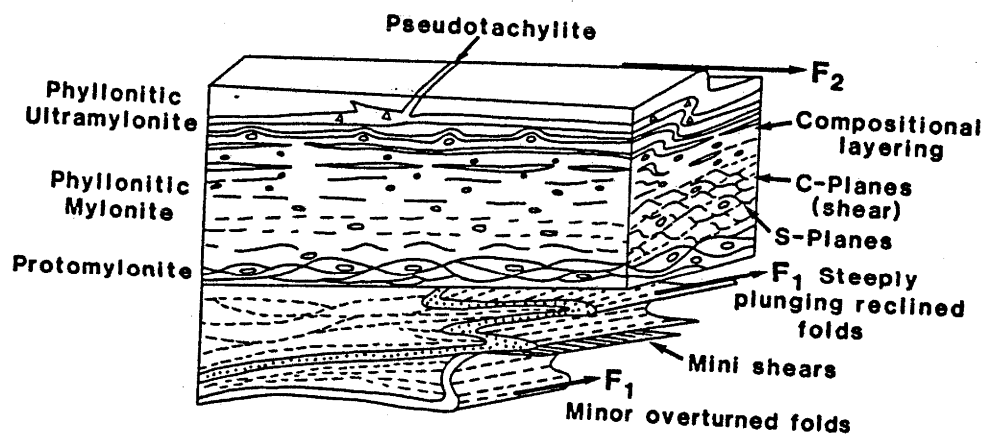


Figure 3-13 Schematic illustration of PT paths for the northern and southern terranes which appear to become concordant after the Ormiston tectonothermal event.

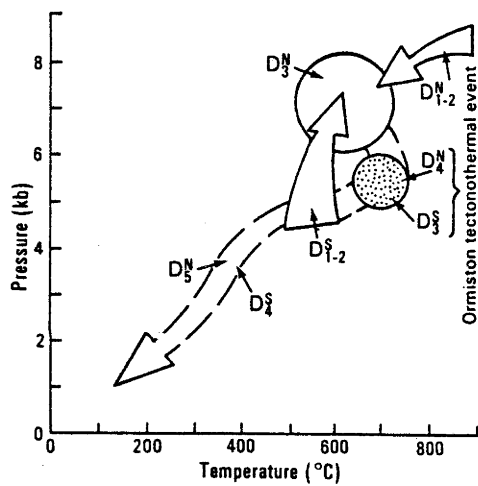


Figure 3-14 Rb-Sr isochron diagram for 1 cm thick rock slabs of sample 8409-1676. Adjacent samples A,B,C,D, and E define an age of 415 ± 50 Ma, which is believed to date the younger deformation. Samples F,G,H, and I fall on a younger line which probably has no direct significance, for these samples are somewhat weathered (see text).

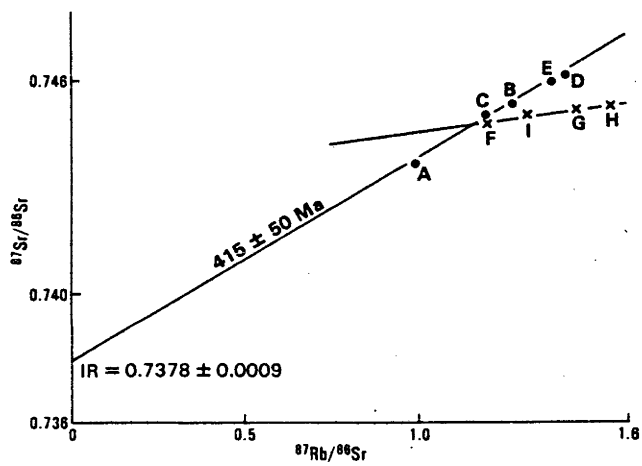


Figure 3-15 Rb-Sr mineral isochron for 8409-1676. The high precision of the age (348 ± 3 Ma) is strongly controlled by the biotite analysis (see text).

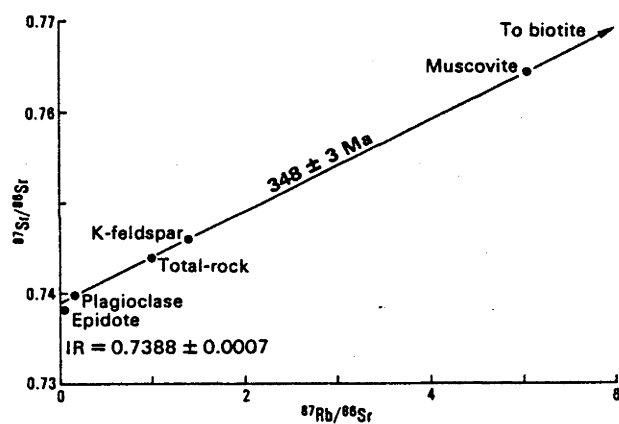


Figure 3-16 Tectonic setting of the region showing the distribution of Late Devonian to Carboniferous faults and their relationships to greenschist facies retrograde metamorphism.

Tectonic features: AH = Amadeus Homocline; ANC = Arltunga /Nappe Complex; BN = Blatherskite Nappe; CF = Charles River Fault; DZ = Delny-Mount Sainthill Fault Zone; GCS = Giles Creek Synform; HZ = Harry Creek Deformed Zone; IZ = Illogwa Creek Schist Zone; JF = Mount Johnstone Fault; NT = Napperby Thrust; OF = Oolmoolmilla Fault; OFZ = Oolera Fault Zone; ON = Ormiston Nappe; PH-HF = Patty Hill-Hann Fault; RZ = Redbank Deformed Zone; RN = Razorback Nappe; TF = Treuer Fault; WT = Waite Creek Fault; YT = Yuendumu Thrust.

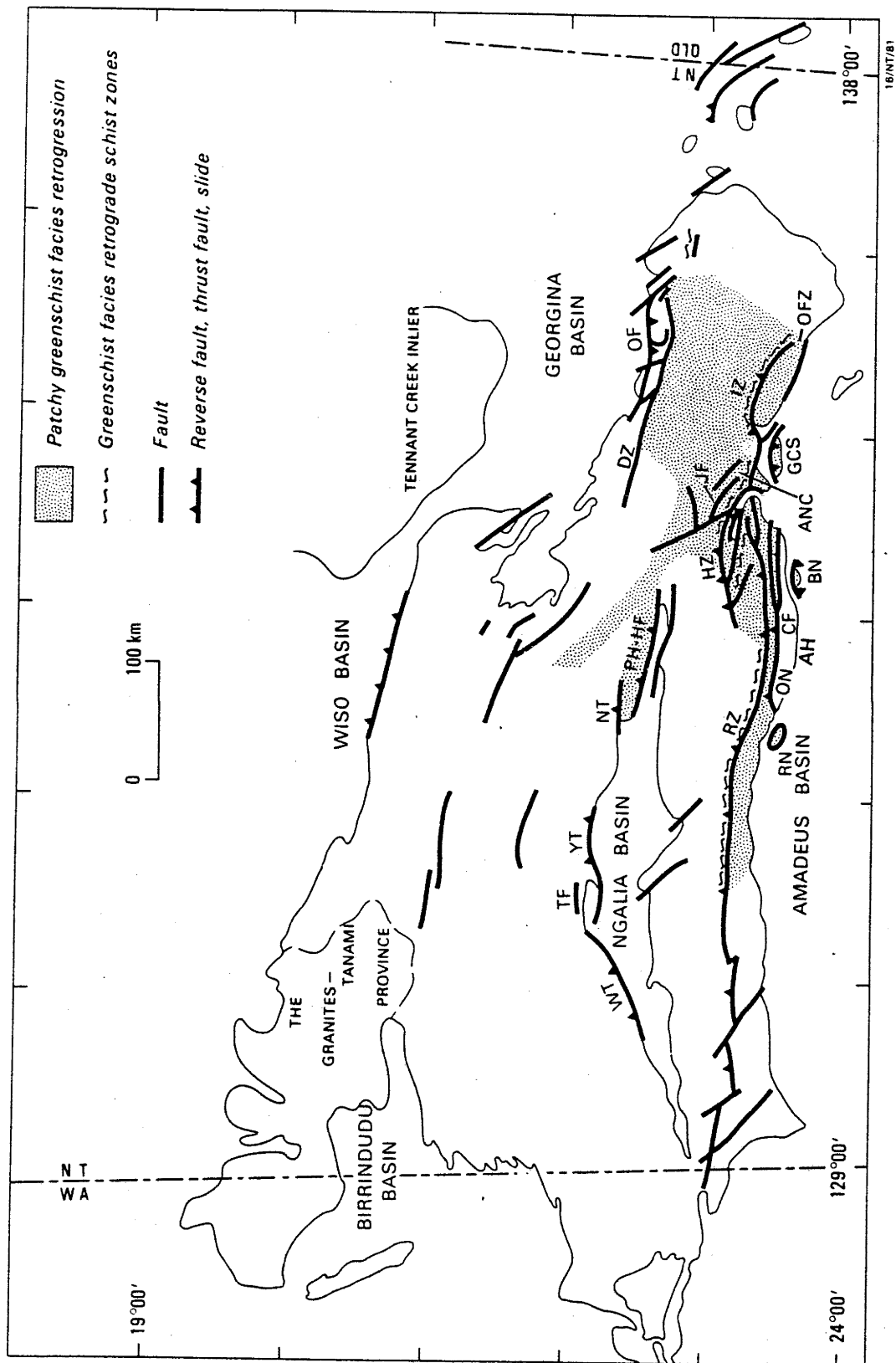


Figure 3-17 Typical types of $^{40}\text{Ar} / ^{39}\text{Ar}$ age spectra

1. Plateau spectrum reflecting rapid cooling with no thermal disturbance.
2. Convex-upwards spectrum recording either episodic loss from a single grain size of spherical crystals or slow cooling.
3. Excess-Ar gain profile.
4. Saddle shaped spectrum recording excess Ar at low and high levels of Ar release.
5. Episodic loss profile where multiple grain sizes are present. The profile displayed also shows a moderate Ar gain profile at low levels of ^{39}Ar release. (See text for further discussion)

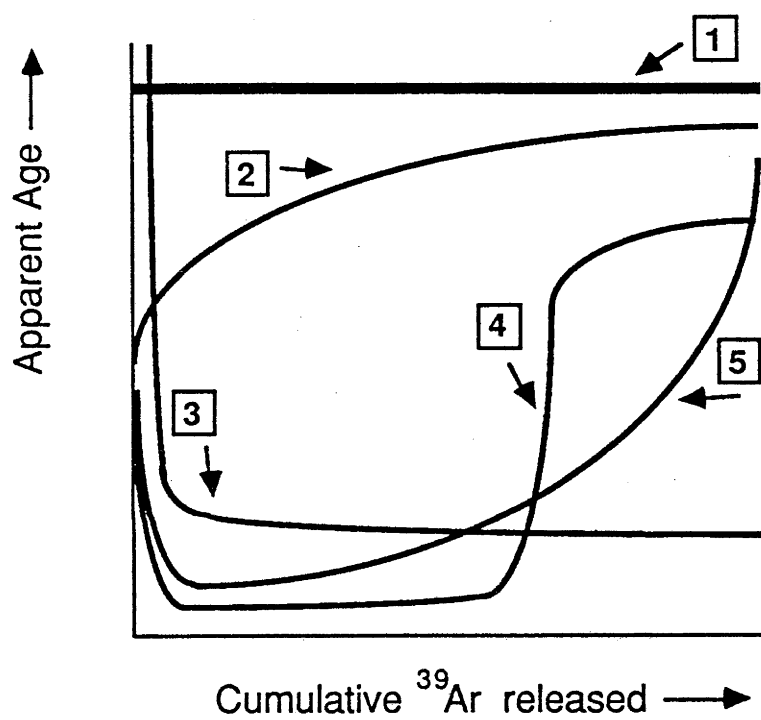


Figure 3-18 Synthetic age spectra for recent episodic argon loss from populations of spheres (after Turner, 1968). Dotted curves are for the Ar loss from grains of uniform size, heavy curves show age spectra expected from a sample consisting of grains showing a log-normal distribution of size. Original crystallization and cooling occurred at 10 Ma. A reheating event took place today.

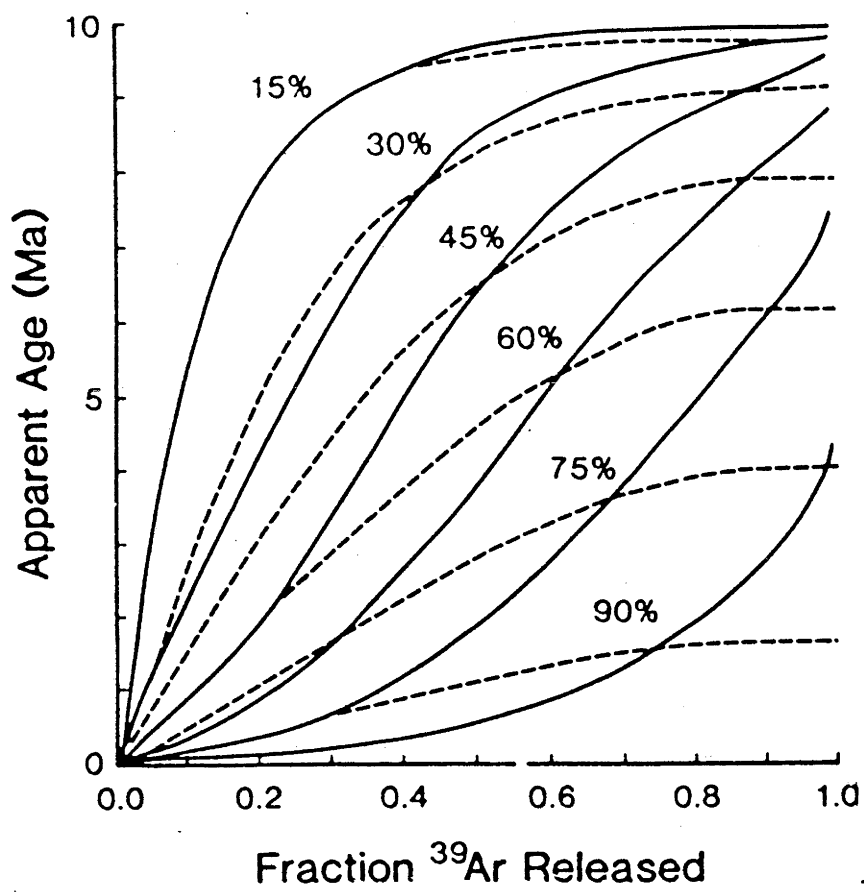


Figure 3-19 Geological cross-section for the Ellery Line (22°41'S, 133°00' E to 24°00' S and 133°00'E) showing the relative position of $^{40}\text{Ar} / ^{39}\text{Ar}$ and K-Ar sample sites and $^{40}\text{Ar} / ^{39}\text{Ar}$ age spectra. The sites are projected parallel to strike onto the section line. Those sites showing the greatest argon loss are shown schematically as the most deeply buried samples in such a way that the surface corresponds to the base of the temperature window for argon loss (assuming a temperature gradient of 25° C/km). Note that the samples have all been uplifted from roughly similar depths. Tectonic features are Amadeus Homocline (AH), Ormiston thrust zone (ON), Redbank Deformed Zone (RDZ), Mount Harris Fault (MF).

Rock unit 1 corresponds to the basin sediments. Rock unit 2 corresponds mainly to granitoid (40%) quartzofeldspathic gneiss (20%) and migmatitic biotite gneiss (35%). Rock unit 3 is similar with a high percentage of granitoid (80%). Rock units 4, 5 and 11 contain progressively larger proportions of mafic granulite (5%, 6%, and 95% respectively), whereas in units 7 and 8 the percentage of mafic granulites decreases (from 65% to 3%). Rock unit 6 is granitoid and Unit 9 comprises granitoid (70%) and metasediments. Rock unit 10 consists of metaquartzite (70%) and other metasediment (30%)

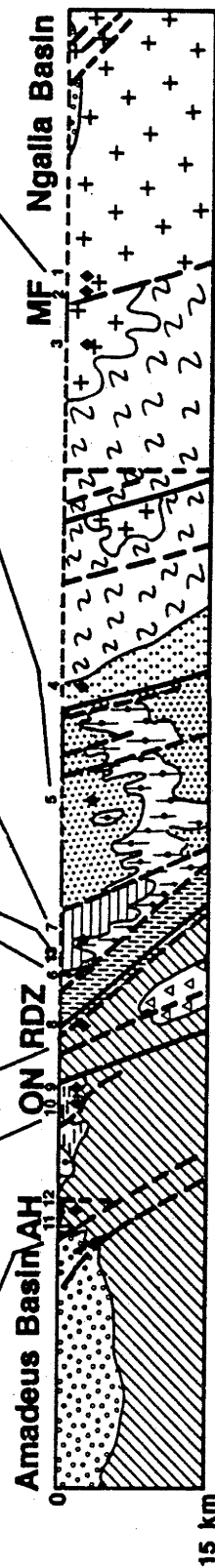
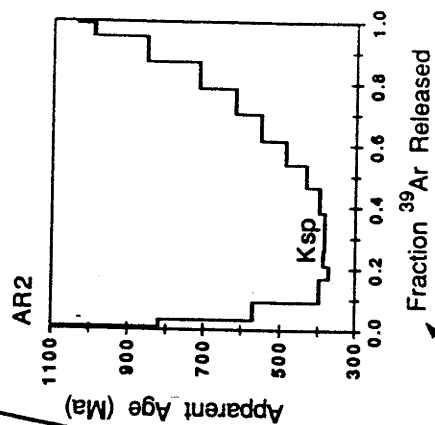
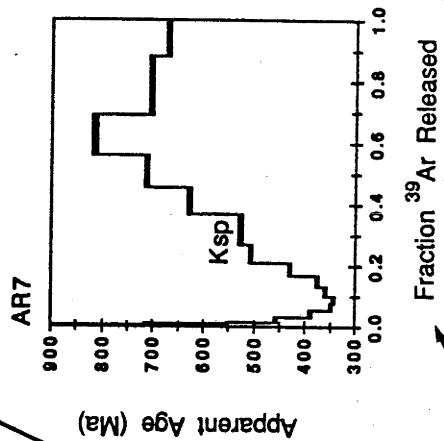
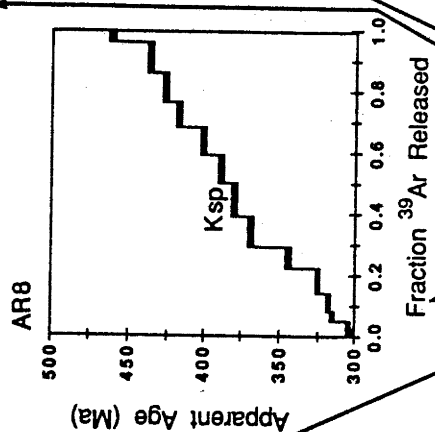
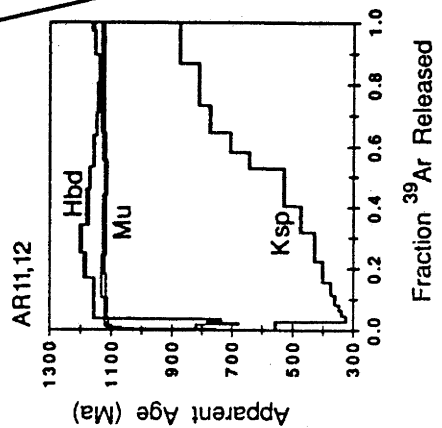
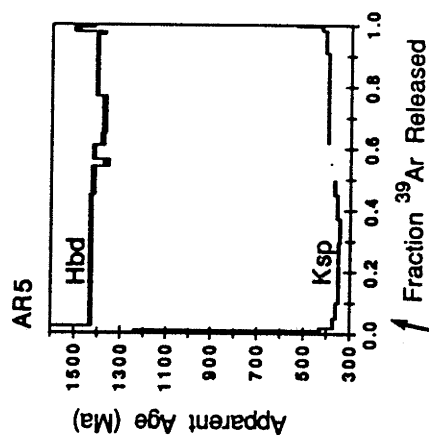
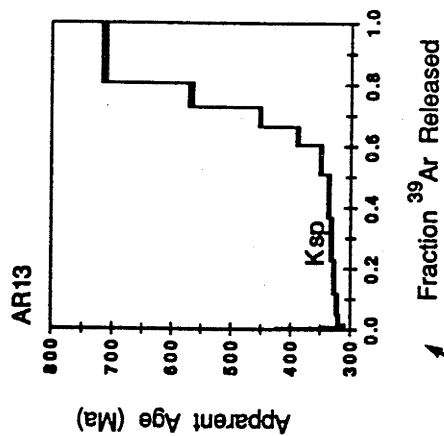
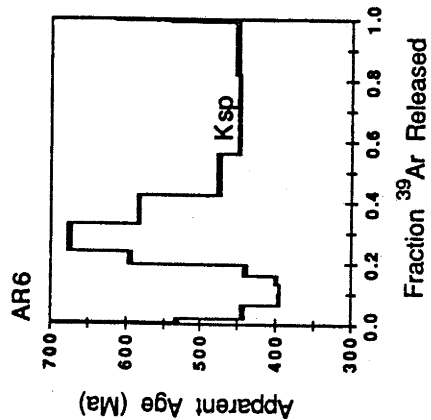
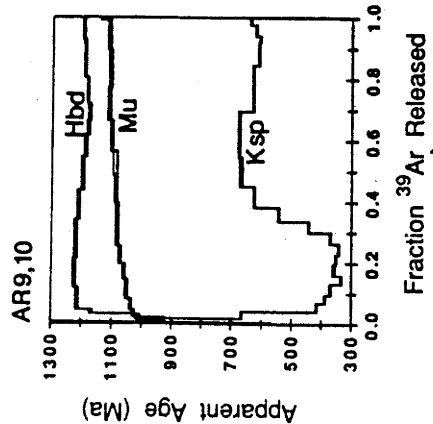
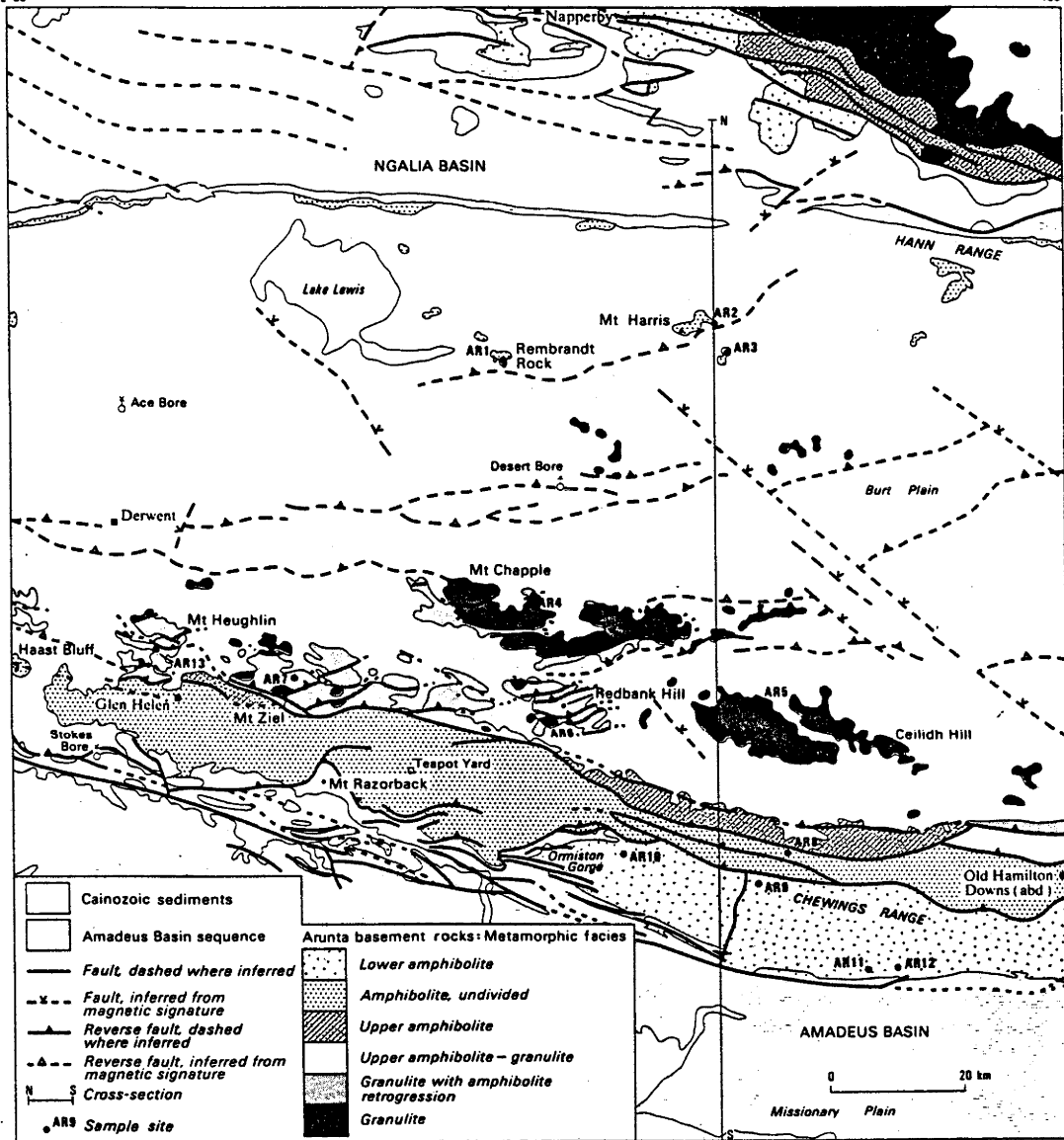


Figure 3-20 $^{40}\text{Ar} / ^{39}\text{Ar}$ and K-Ar sample sites located on map showing the distribution of metamorphic facies and major faults in the Arunta Basement between the Amadeus and Ngalia basins. The position of the Ellery cross-section (NS) is also shown. Faults shown in the west of the Ngalia Basin are based on drilling by Agip (Aust) Pty Ltd as reported by Saucier, pers. comm., 1985)

132°00'

133°30' 22'30"

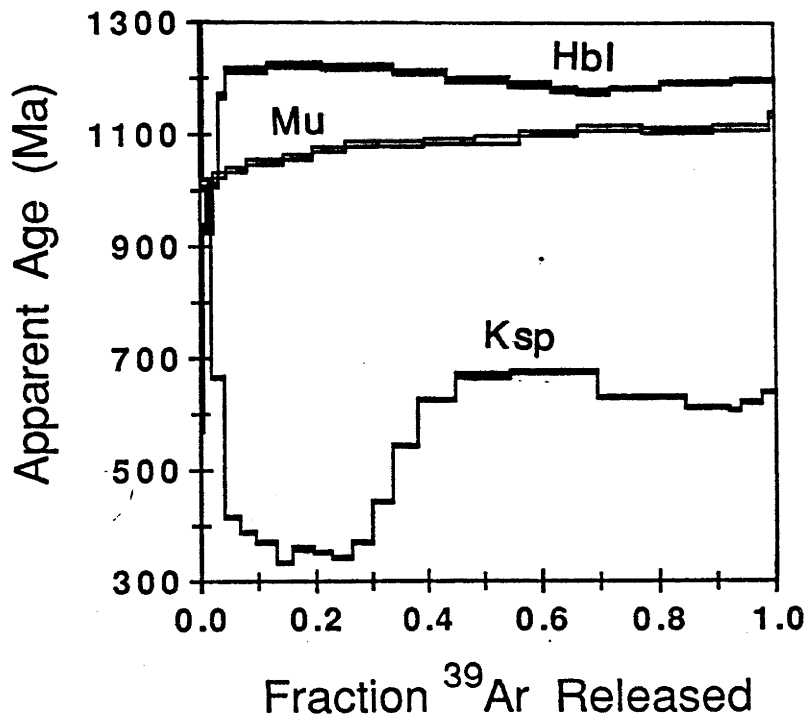


• 18/F53-13/11 24°0'

Figure 3-21 $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for hornblende, muscovite and K-feldspar for sites Ar9 and Ar10 combined and for Ar11 and Ar12 combined. The sites Ar11 and Ar12 are from a tectonic block dominated by granitic gneisses (muscovite and amphibolite hornblende) metamorphosed in the lower to middle amphibolite facies, and were from the initially more deeply buried northern margin of the block. Sites Ar11 and Ar12 are adjacent to sediments of the Amadeus Basin within the Amadeus Homocline (see Fig. 3-20).

AR10 AR9

86-136 Hbl 86-124 Musc 86-132 Ksp



AR11 AR12

86-135 Hbl 86-123 Musc 86-125 Ksp

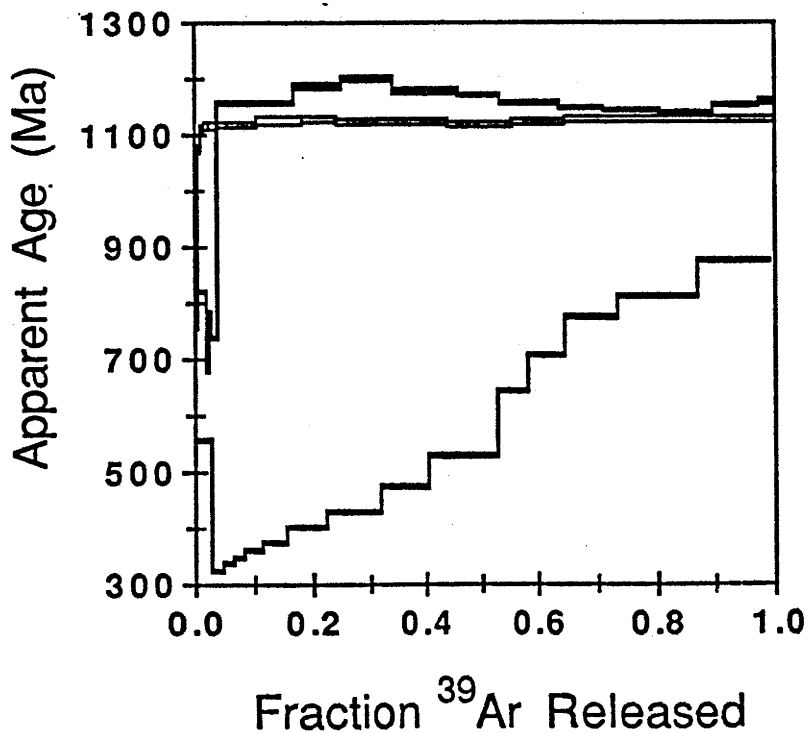
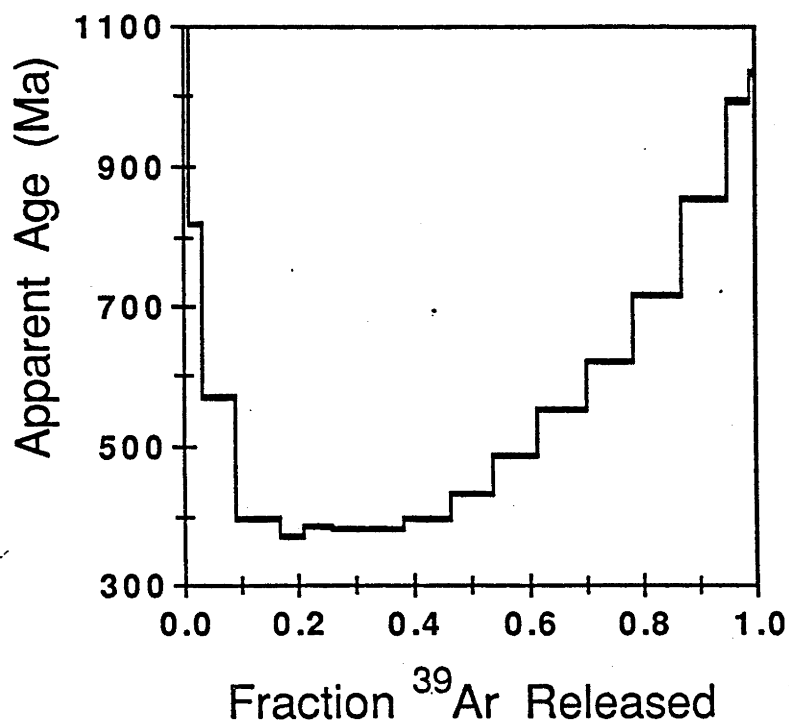


Figure 3-22 $^{40}\text{Ar} / ^{39}\text{Ar}$ age spectra for K-feldspars from site Ar2 near the Ngalia Basin and for K-feldspar and hornblende from site Ar5 from within the granulite terrane (see Fig. 3-20).

AR2

86-131 Ksp



AR5

86-134 Ksp 86-122 Hbl

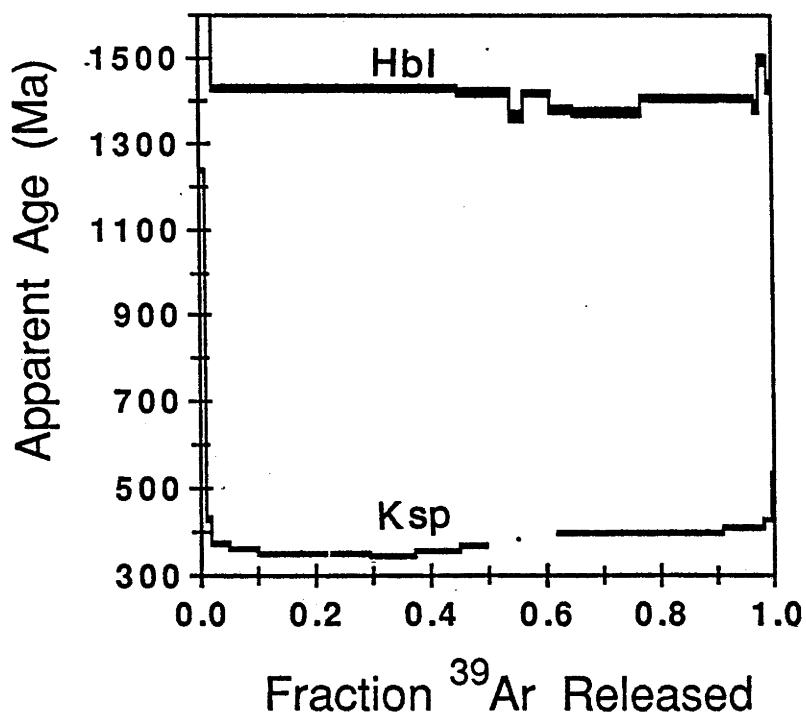
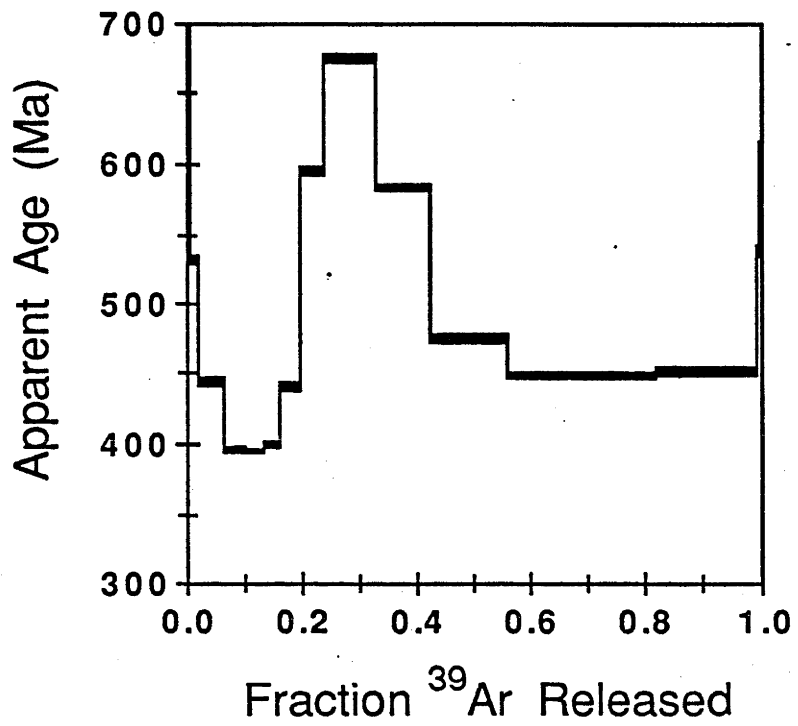


Figure 3-23 $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for

- (1) Site Ar6: a deformed K-feldspar megacryst from mylonites of the Redbank Deformed zone; and
- (2) K-feldspar from site Ar8 (i.e from granitic gneiss, metamorphosed at amphibolite grade, and then sandwiched between two major Palaeozoic thrusts. See Fig. 3-20)

AR6

86-126 Ksp



AR8

86-133 Ksp

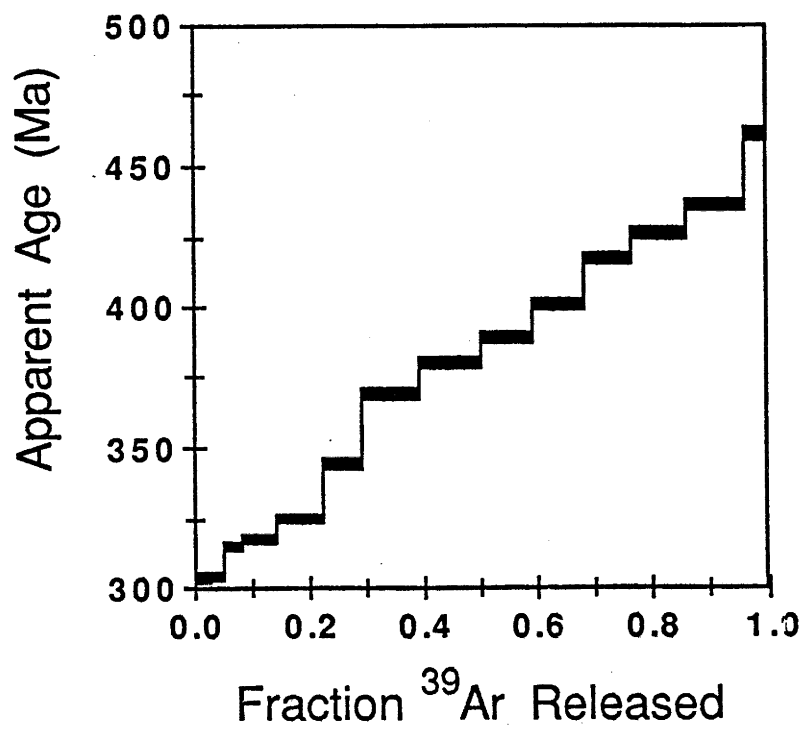


Figure 3-24 $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for K-feldspars in granitic gneiss from site Ar7 and in ultramylonite from Ar13.

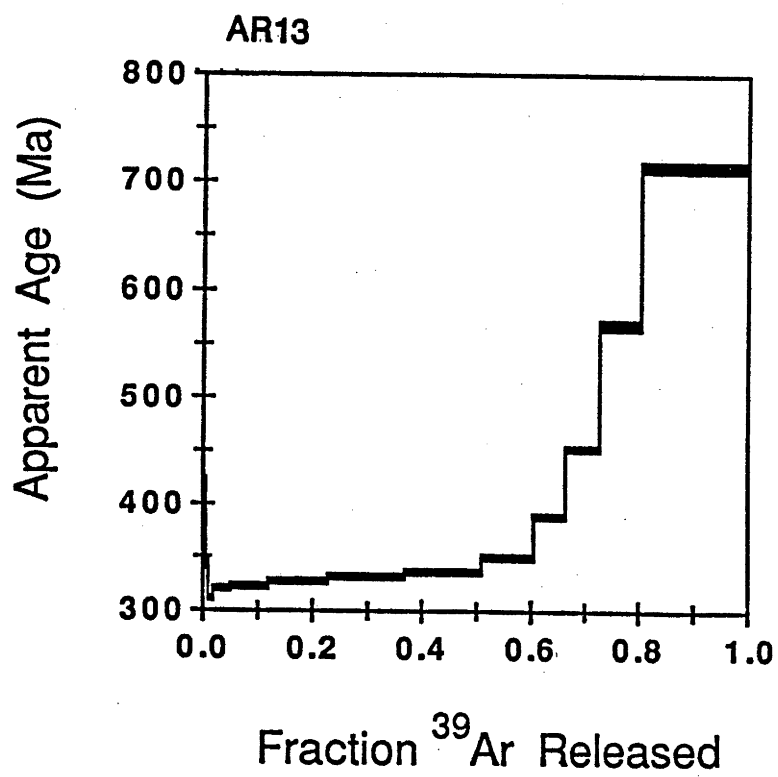
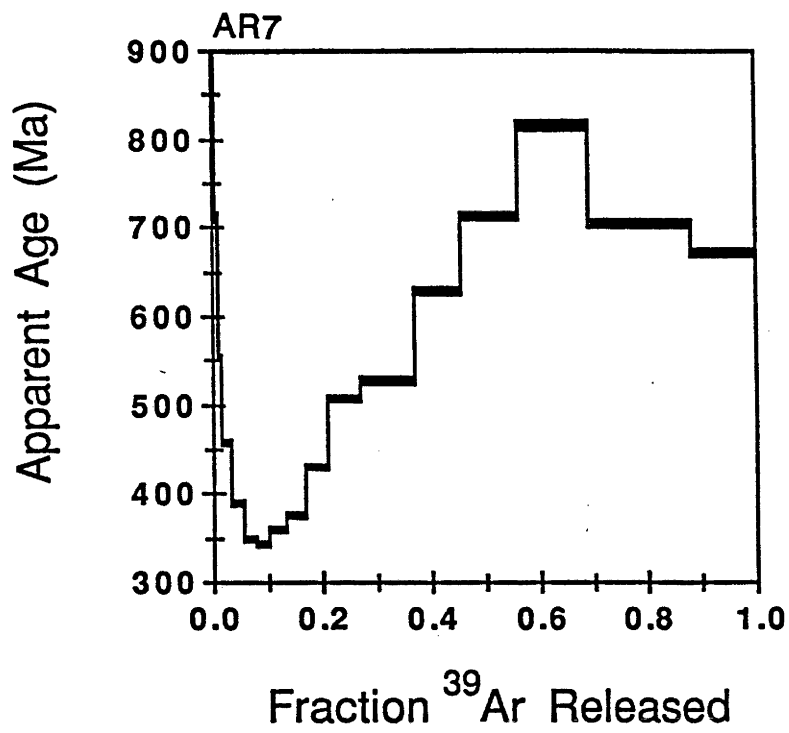


Figure 3-25 Argon loss in K-feldspars relative to the original crustal level of the specimens. An approximate crustal level is established on the basis of metamorphic facies shown in Fig. 3-20. Abbreviations: GS- Greenschist; UA- Upper Amphibolite; LA- Lower Amphibolite; GN- Granulite

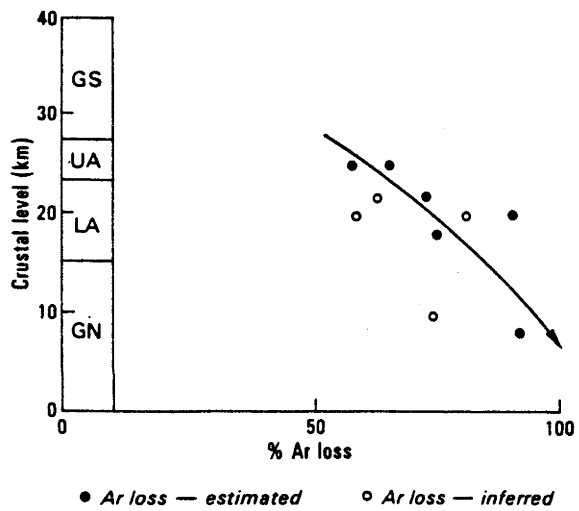


Figure 3-26 Estimates of diffusion parameters in K-feldspar $^{40}\text{Ar} / ^{39}\text{Ar}$ experiments: 1) frequency factor relative to the effective dimensions of the crystal (D_0/a^2) and 2) the activation energy (E). For a cooling rate of $10^\circ\text{C}/\text{Ma}$ these parameters yield a closure temperature of 332°C (see text for discussion).

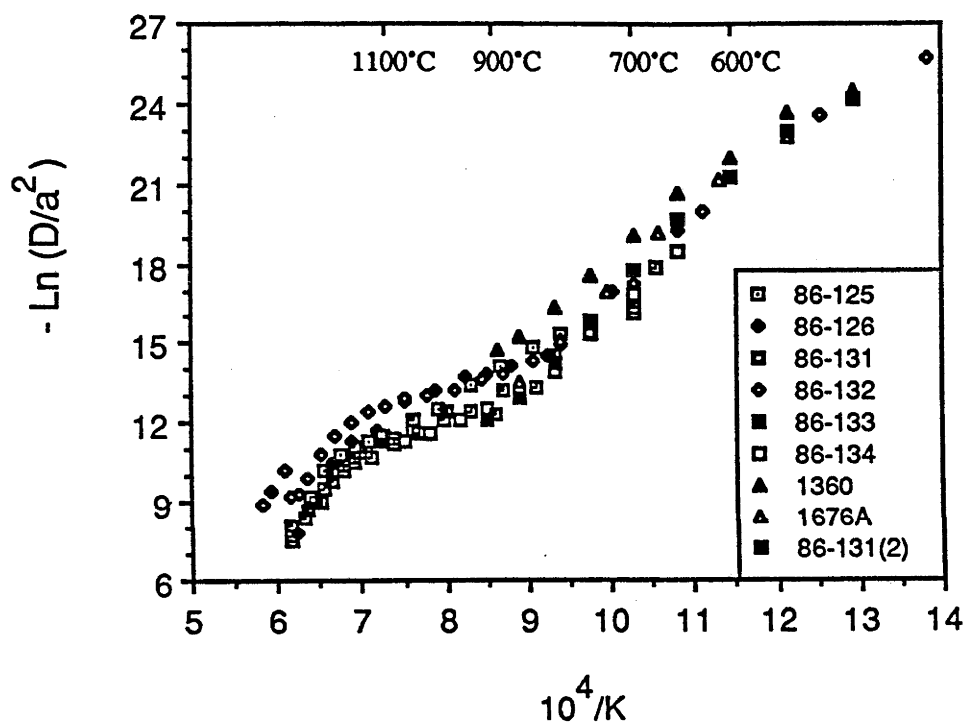


Figure 3-27 Partial argon loss nomograms for a series of square thermal pulses using equations 2-3, 2-4 and 2-5, assuming 332°C closure temperature deduced from diffusion parameters averaged for all experiments. For these conditions there is a sharp cut-off for rapid argon loss at about 240-250° as illustrated further in Fig.3-29. Semiquantitative estimates (see Table 3-19) suggest most samples experienced argon losses in excess of 60%. Argon loss (64%) is marked for site Ar11 (86-125): loss for the remaining specimens fall between 65% (inferred from K-Ar age at Site Ar7, specimen 87-88) and 91% ($^{40}\text{Ar} / ^{39}\text{Ar}$ spectra at site Ar8, specimen 86-133) (see Table 3-19).

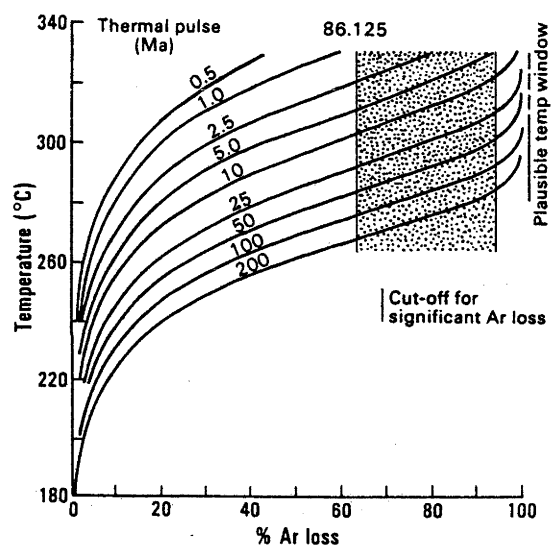


Figure 3-28 Transient temperature gradients deduced for several rates of sedimentation and erosion for equilibrium geothermal gradients of 15°C/km, 25°C/km and 30°C/km. In these models 5 km of sediment are added to an initial 5 km-thick sedimentary pile. Curve 1 is the temperature-time path at the base of the sedimentary column. Curve 2 is the transient geothermal gradient after one thickness. Curve 3 is for the gradient once burial is complete. Estimates for the rate of thermal relaxation (after the cessation of sedimentation) assume that equilibrium is reached in a period three times the thermal constant (for that depth taken to be about 3 Ma at a depth of 10 km; see Turcotte and Schubert, 1982, p.151). The solution is from the one dimensional equation for heat conduction in a moving medium surface (Jaeger, 1965, eqn 36), assuming a linear rate of subsidence or uplift.

The temperature ($T^{\circ}\text{C}$) at time $t(\text{s})$ and depth $Z(\text{m})$ is given by:

$$T = \frac{1}{2} g \left\{ (z+Ut) \exp \left(\frac{Uz}{K} \right) \operatorname{erfc} \left[\frac{(Z+Ut)}{(2(Kt))^{1/2}} \right] - (z-Ut) \operatorname{erfc} \left[\frac{(z-Ut)}{(2(Kt))^{1/2}} \right] \right\}$$

where U is the sedimentation rate(m/s)

g is the geothermal gradient ($^{\circ}\text{C}/\text{m}$)

K is the diffusivity taken to be $1 \times 10^{-6} (\text{m}^2 \text{s}^{-1})$

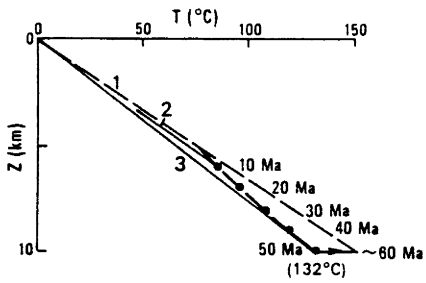
erfc is a supplied error function $\operatorname{erfc}(\xi) = 1 - \operatorname{erf}(\xi)$

$\operatorname{erf}(-\xi) = -\operatorname{erf}(\xi)$

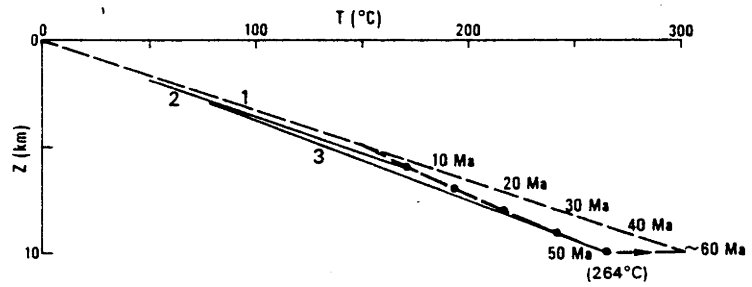
and the surface temperature is assumed to be zero.

For example the plot in the top LHS of the Figure shows the progressive depth and temperature (sample = dots) for a sample buried at the rate of 100m/Ma under a geothermal gradient of 15°C/km. The geothermal gradient evolves from its initial value (curve 1) to a transient value after 1000m of sediment are added and finally to its minimum value (curve 3) after 5km of sediment have been added in a total of 50 Ma. About 10 Ma or less is required for the temperature to return to its equilibrium value (at about 60 Ma).

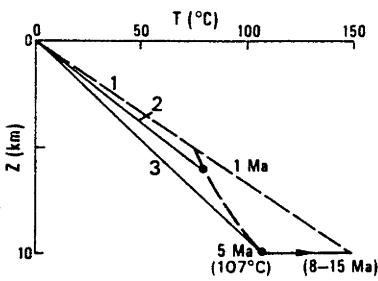
BURIAL
100m/Ma, 15°C/km



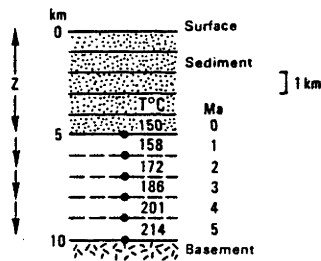
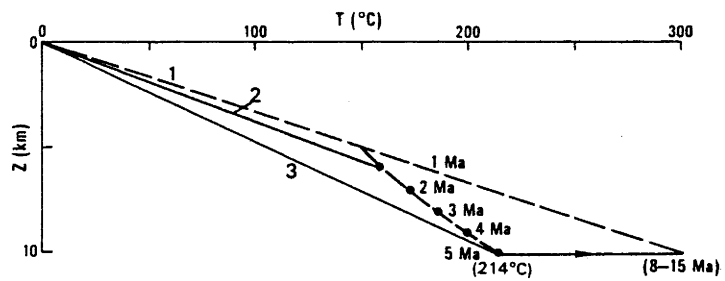
BURIAL
100m/Ma, 30°C/km



BURIAL
1km/Ma, 15°C/km

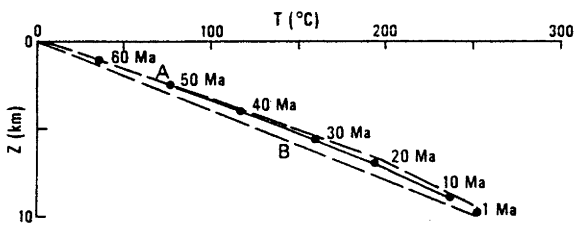


BURIAL
1km/Ma, 30°C/km

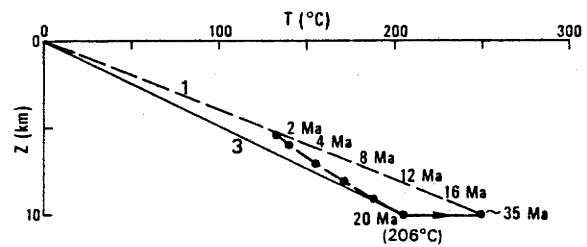


UPLIFT

A = 150m/Ma, 25°C/km, 3.5°C/Ma
B = 100m/Ma, 25°C/km, 2.2°C/Ma

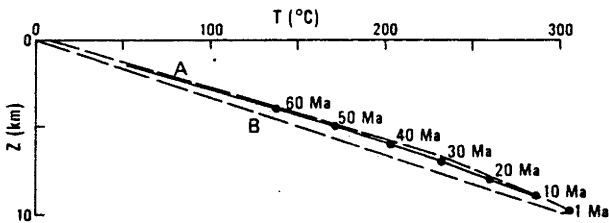


BURIAL
250m/Ma, 25°C/km



UPLIFT

A = 150m/Ma, 30°C/km, 4.2°C/Ma
B = 100m/Ma, 30°C/km, 2.6°C/Ma



BURIAL
250m/Ma, 30°C/km

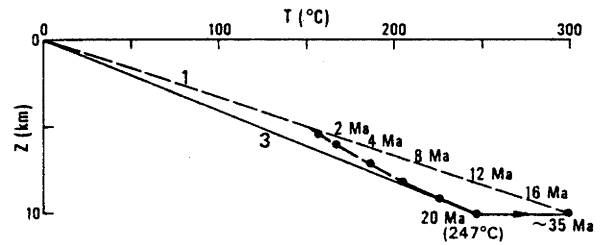


Figure 3-29 Semi-quantitative model for the temperature/time history for the thermal pulse at site Ar11. Model 1 accounts for the 64% argon loss from K-feldspar at site Ar11 by addition of overburden at a rate of 250m/Ma for a geothermal gradient of 25°C/km. The fast accumulation rate induces a transient geothermal gradient (see Fig.3-28). Progressive depth of burial is indicated (e.g. 9000m, ~ 12000m). Erosion at a rate of 100m/Ma reduces the temperature of the specimen at Ar11 to 110-120° by 260 Ma. Argon loss is estimated by the diffusion equations for a sphere given in Mussett (1969) and Crank (1979).

Model 2 assumes that 2.75 km of overburden accumulated at a slow rate (about 100 m /Ma) to a peak temperature of about 288°C, assuming a geothermal gradient of 25°C/km. Conditions remained stable for about 10 Ma before renewed uplift of about 7.5 km occurred between 310-340 Ma and 260 Ma resulting in cooling at a rate of about 3°C/Ma. Uplift accompanied by a cooling rate of 0.3 – 0.4°C/Ma continued from 260 Ma until the present.

Model 3 is for the 50 Ma, square, thermal pulse which produces the same argon loss under similar conditions.

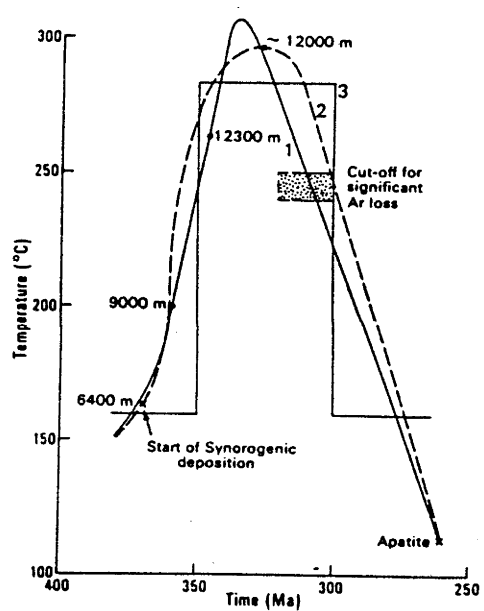


Figure 3-30 Schematic plots of temperature/time history (Tt) for specimens south and north of the RDZ derived from the interpreted ages of hornblende and muscovite cooling and the temperatures deduced in modeling for the thermal pulse determined from the episodic Ar loss in the feldspar of Ar11. Also shown are inferred depth-time (Zt) plots assuming a geothermal gradient of 25°C/km and equilibrium thermal conditions (dot = conodont paleontological control). The final Tt control is derived from opatite data (Table 3-18). (See text for discussion).

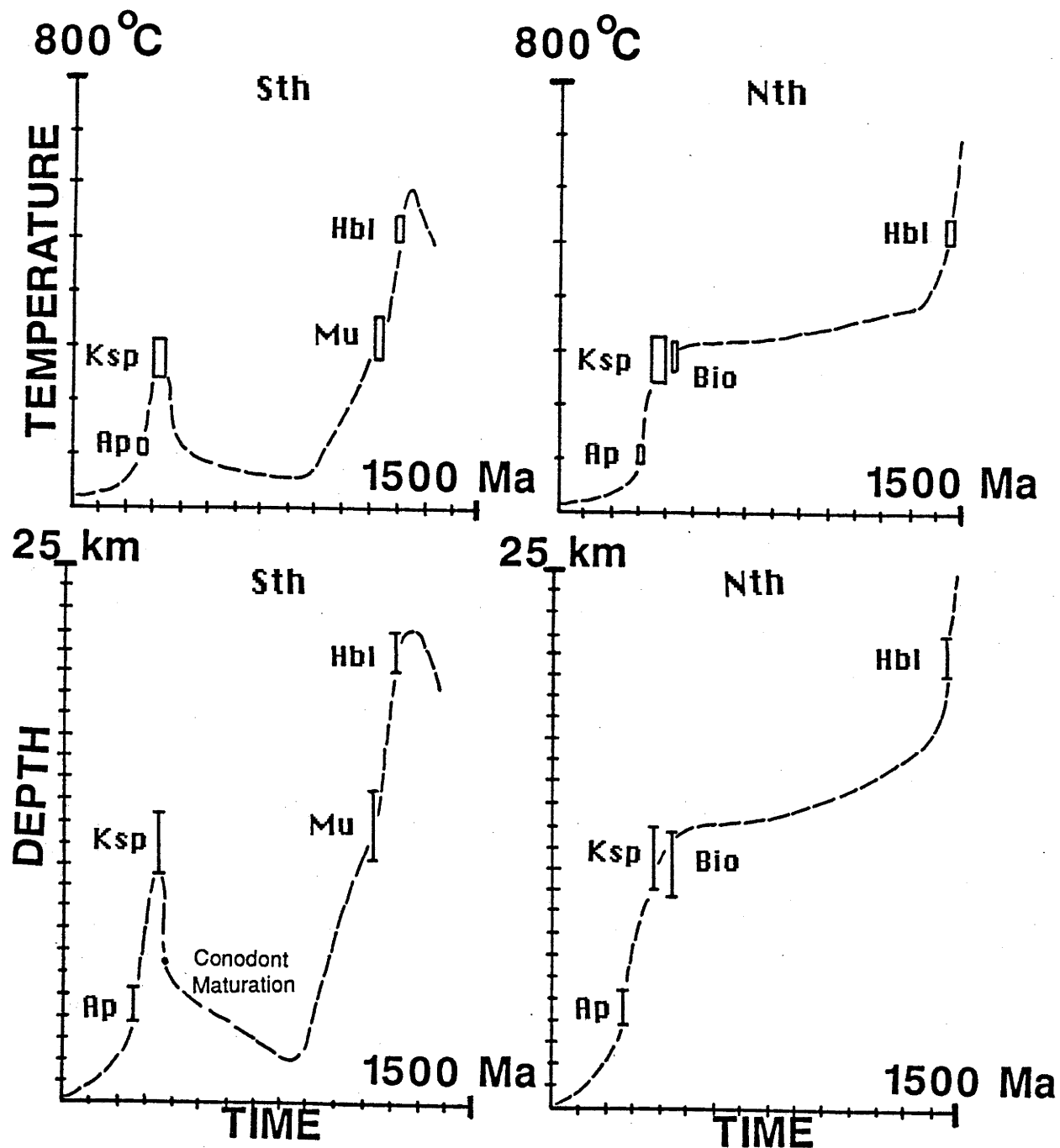
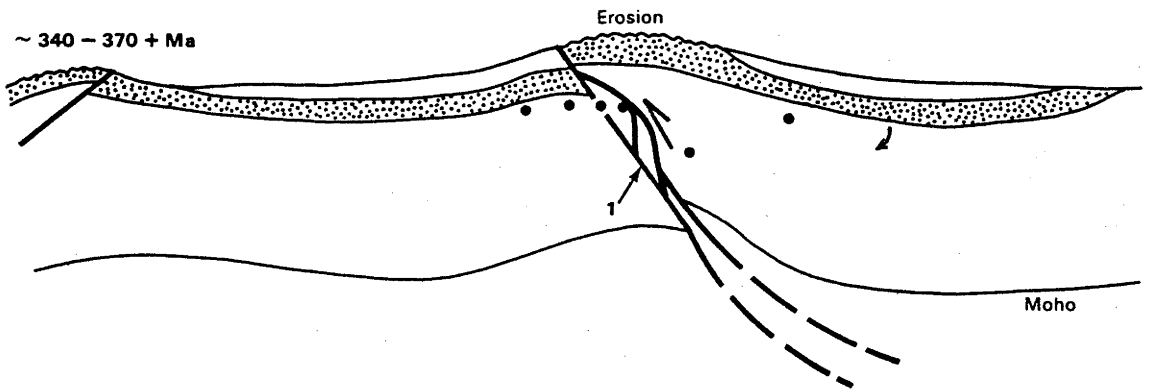


Figure 3-31 Schematic sketch of plausible 'piggy-back' uplift history consistent with the regional geology and $^{40}\text{Ar} / ^{39}\text{Ar}$ data (sample sites shown by dots). Total uplift of the granulite facies terrane north of fault 1 (RDZ) is inferred to be approximately equal to the sum of the uplifts on each of the fault zones 1=RDZ, 2=ON, 3=AH (Some faulting as well as flexure is implied on the AH; see also Figs 2-3, 2-4 and 2-5). It is speculated that uplift on each fault zone separating crustal blocks was roughly 10 km, suggesting a total uplift of roughly 30 km spread over about 100 Ma (see text for discussion). Because the fault zones dip at about 45° , total lateral (horizontal) shortening of similar magnitude is implied. In the first stage (ca 340-370 Ma), the northern terrane was uplifted on fault zone 1 (RDZ) and at the same time tilted downwards to the north. Synorogenic sediments were rapidly deposited in the Amadeus Basin (AB) and in the Ngalia Basin (NB). In the second stage (ca 330-340 Ma), the whole northern terrane was uplifted on fault zone 1 (RDZ), but the northernmost part of the northern terrane underwent negligible uplift and minor lag faulting (L) with a normal sense of movement occurred. In the third stage (ca 260-300 Ma), uplift was completed by movement on fault zones 2 (ON), and 3 (AH). The crust between fault zones 1 and 3 also shortened and thickened due to bulk inhomogenous strain. Minor 'thin-skinned' thrusting occurred north of the Ngalia Basin (NB).

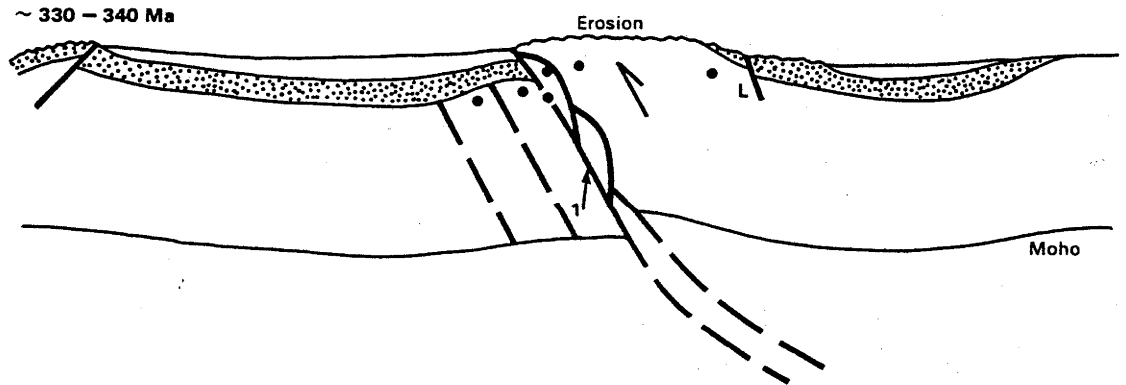
SOUTH

NORTH

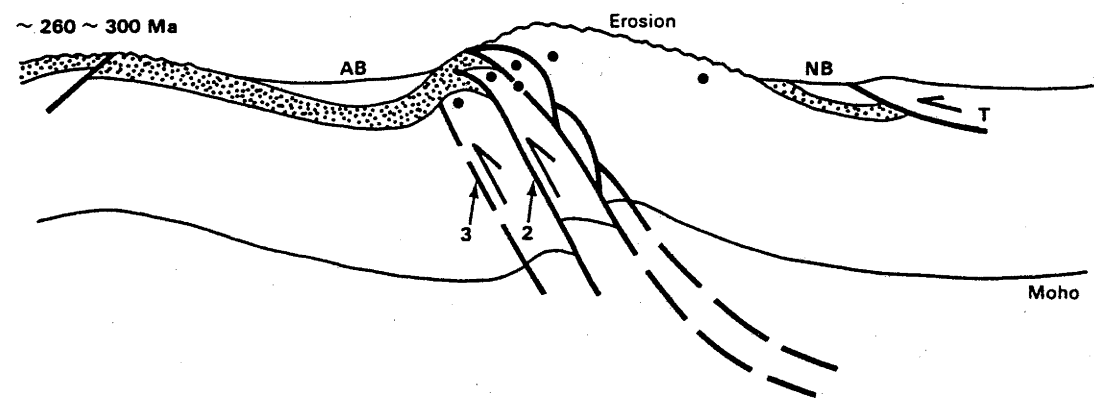
~ 340 - 370 + Ma



~ 330 - 340 Ma



~ 260 ~ 300 Ma



CHAPTER 4

BASIN DEVELOPMENT IN CENTRAL AUSTRALIA

Figure: 4-1. Time-thickness plots based on tectonostratigraphic correlations of Late Proterozoic units in the central Australian basins and in the Adelaide Geosyncline. The infilled triangle at the left hand side of the diagram represents the inferred time-span of glaciation.

Northern Amadeus Basin: D = Chandler Formation, T = Todd River Dolomite, A = Arumbera Sandstone 3 & 4, Z = Arumbera Sandstone 1 & 2, J = Julie Formation, E = Pertatataka Formation, O = Olympic Formation, LM = Limbla Member of Aralka Formation, L = Lower Aralka Formation, Y = Areyonga Formation, I = Bitter Springs Formation, Q = Heavitree Quartzite.

Adelaide Geosyncline: AC = Aroona Creek Limestone, BC = Billy Creek Formation, FT = Forke Tree Limestone, Sellick Hill Formation, TV = Troro Volcanics, WL = Wilkawillina Limestone, PR = Parachilna Formation, UR = Uratanna Formation, PS = Pound Subgroup, WN = Wonoka Formation, ABC = ABC Range Quartzite, BR = Brachina Subgroup of Wilpena Group, BN = Bunyerroo Formation, NC = Nuccaleena Formation of Wilpena Group, YS = Yerelina Subgroup (includes Pepuarta Tillite), AF = Angepena Formation, BL = Brighton Limestone, TH = Tapley Hill Formation, ST, AP = Sturt Tillite, Appila Tillite. YD = Yudnamutana Subgroup, BS = Belair Subgroup, SW = Saddleworth Formation, AD = Auburn Dolomite, SK = Skillogalee Dolomite, UQ = Undalya Quartzite, WS = Woodshed Flat Shale, EQ = Emeroo Quartzite, AS = Aldgate Sandstone, CB = Callanna beds, BV = Beda Volcanics.

Western Georgina Basin: ER = Errarra Formation, MB = Mount Baldwin Formation, MP = Mopunga Group (Elkera, Grant Bluff & Elyuah Formations), OA = Oorabra Arkose, MC = Mount Cornish Formation, YB = Yackah beds.

Ngalia Basin: WD = Walbiri Dolomite, YS2 = Upper Yuendumu Sandstone, YS1 = Lower Yuendumu Sandstone, MD = Mount Doreen Formation, RS = Rinkabeena Shale, NF = Naburula Formation, AF = Albinia Formation, VS = Vaughan Springs Quartzite.

Officer Basin: TH = Table Hills Volcanics (age 575 ± 40 Ma; Compston, 1974) = Kulyong Volcanics, OS = Observatory Hill beds, BA = Babbagoola beds (= Wallantina Formation), WO = Woolnough beds, PB = Punkerri beds, RB = Rodda beds, TH = Tapley Hill Formation, LB = Lupton Beds, WV = Wantapella Volcanics, CB = Chambers Bluff Tillite, BF = Brown beds, WB = Wright Hill Beds, TQ = Townsend Quartzite.

Age Control References:

- (1) Fauna is Atabanian to early Lenian (Laurie & Shergold, 1985)
- (2) Arumbera Sandstone straddles Cambrian/Precambrian boundary (Conrad, 1981; Cowie & Glaessner, 1975), dated in China at about 605-610 Ma
- (3) 650-660 Ma age estimate for base of Ediacarian Period (Cloud & Glaessner, 1982, Glaessner, 1983).
- (4) 676 ± 204 Ma Rb-Sr date on Woomera Shale Member of Brachina Formation (Webb in Thomson, 1980).
- (5) 750 ± 53 Ma Rb-Sr date on shale in Tapley Hill Formation (Webb in Thomson, 1980)
- (6) 900 ca Ma Rb-Sr date on Stuart Dyke Swarm (Black et al, 1980).
- (7) 1076 ± 34 Ma date on Beda Volcanics (Webb in Thomson, 1980)
- (8) 1140 Ma Rb-Sr date for Ormiston Event (Shaw and Black, in press, cf. Marjoribanks and Black, 1974).
- (9) 574 ± 40 Ma Table Hills Volcanics (Compston, 1974).

General References: Coates, 1973; Freeman, 1986; Rutland et al, 1981; Walter, 1981; Jackson & Van de Graaff, 1981; Preiss & Forbes, 1981; Shergold et al, 1985; Webb & Coates, 1980; Wells & Moss, 1983; Wells et al, 1970.

Figure: 4-2. Palaeozoic time-thickness plots for the central Australian basins (Northern Amadeus, Georgina, Ngalia and Canning basins).

Amadeus Basin : B = Brewer Conglomerate, H = Hermannsburg Sandstone, P = Parke Siltstone, M = Mereenie Sandstone, C = Carmichael Sandstone, S = Stokes Siltstone, R = Stairway Sandstone, V = Horn Valley Siltstone, F = Pacoota Sandstone, G1 = Lower Goyder Formation, G2 = Upper Goyder Formation, N = Shannon Formation, U = Hugh River Shale, K = Giles Creek Dolomite, D = Chandler Formation, T = Todd River Dolomite, A = Upper Arumbera Sandstone.

Georgina Basin : DS = Dulcie Sandstone, ES = Ethabuka Sandstone, MF = Mithaka Formation, CS = Carlo Sandstone, NF = Nora Formation, TB = Tomahawk beds, KC = Kelly Creek Formation, NN = Ninmaroo Formation, GL = Georgina Limestone, BS = Blazan Shale, AF = Arrinthrunga Formation, AC = Arthur Creek Formation, TL = Thornton Limestone, ER = Errarra Formation, MB = Mount Baldwin Formation, SS = Correlate of Sun Hill Arkose.

Ngalia Basin: ME = Mount Eclipse Sandstone, K = Kerridy Sandstone, DF = Djagamara Formation, BF = Bloodwood Formation, WD = Walbiri Dolomite, YS2 = Upper Yuendumu Sandstone.

Canning Basin : PH = Pike Hills Formation, MF = Meeringerie Formation, TF = Tandagaloo Formation, WF = Worrall Formation, CG = Carribuddy Group, NT = Nita Formation, GW = Goldwyer Formation, WL = Willara Formation, NA = Nambett Formation.

Age Control References: Young, 1985; Kennard & Nicoll, 1986; Shergold (1987); Laurie & Shergold, 1985; Kruse & West, 1980; Playford et al, 1976; Gilbert-Tomlinson in Wells et al, 1970; Lehmann, 1984; Forman & Wales, 1981; Wells & Moss, 1983; Freeman, 1986; Morris, 1986; Wells et al, 1970; Shergold et al, 1985; Kennard & Nicoll, 1986.

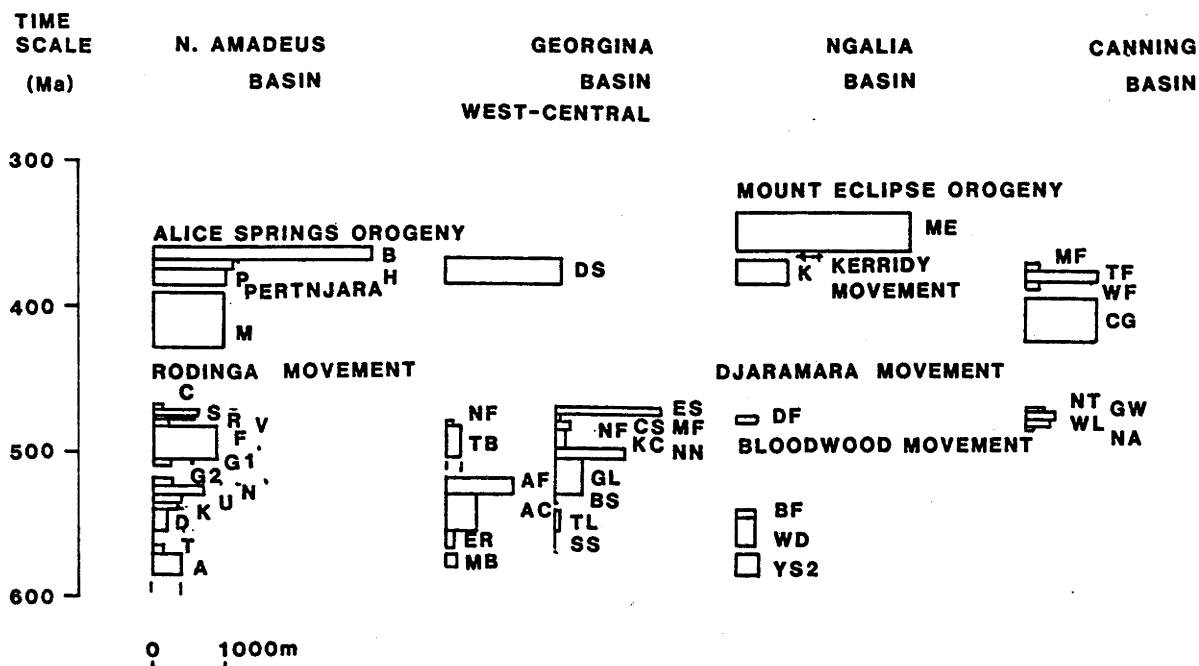


Figure 4-3. Composite subsidence curve constructed for the northern Amadeus Basin assuming Airy isostatic conditions. The relationships of subsidence history to sediment type and to tectonic events are also indicated (see text for explanation). The orogenic events are: R = Arunta Movement (uplift of Arunta block following Ormiston Tectothermal Event), A Areyonga Movement (750-800 Ma, possibly 750 Ma+), S South Range Movement (680-700 Ma?), H Huckitta Movement (Cambrian-Precambrian boundary), D Delamerian Orogeny (in Kanmantoo Fold Belt: D1 about 505-520 Ma, D2 about 480-495 Ma), B Benambran Orogeny (in Lachlan Fold Belt (LFB) 440?-430 Ma), preceded by widespread hiatus from mid-Ordovician), T Tabberabberan Orogeny (in LBF about 380-390 Ma) correlated with Pertnjara Movement in central Australia), K Kanimblan Orogeny (in LBF Early to mid-Carboniferous or about 320-350 Ma), correlated with Alice Springs Orogeny in central Australia (at about 370?-320 Ma).

BASEMENT SUBSIDENCE

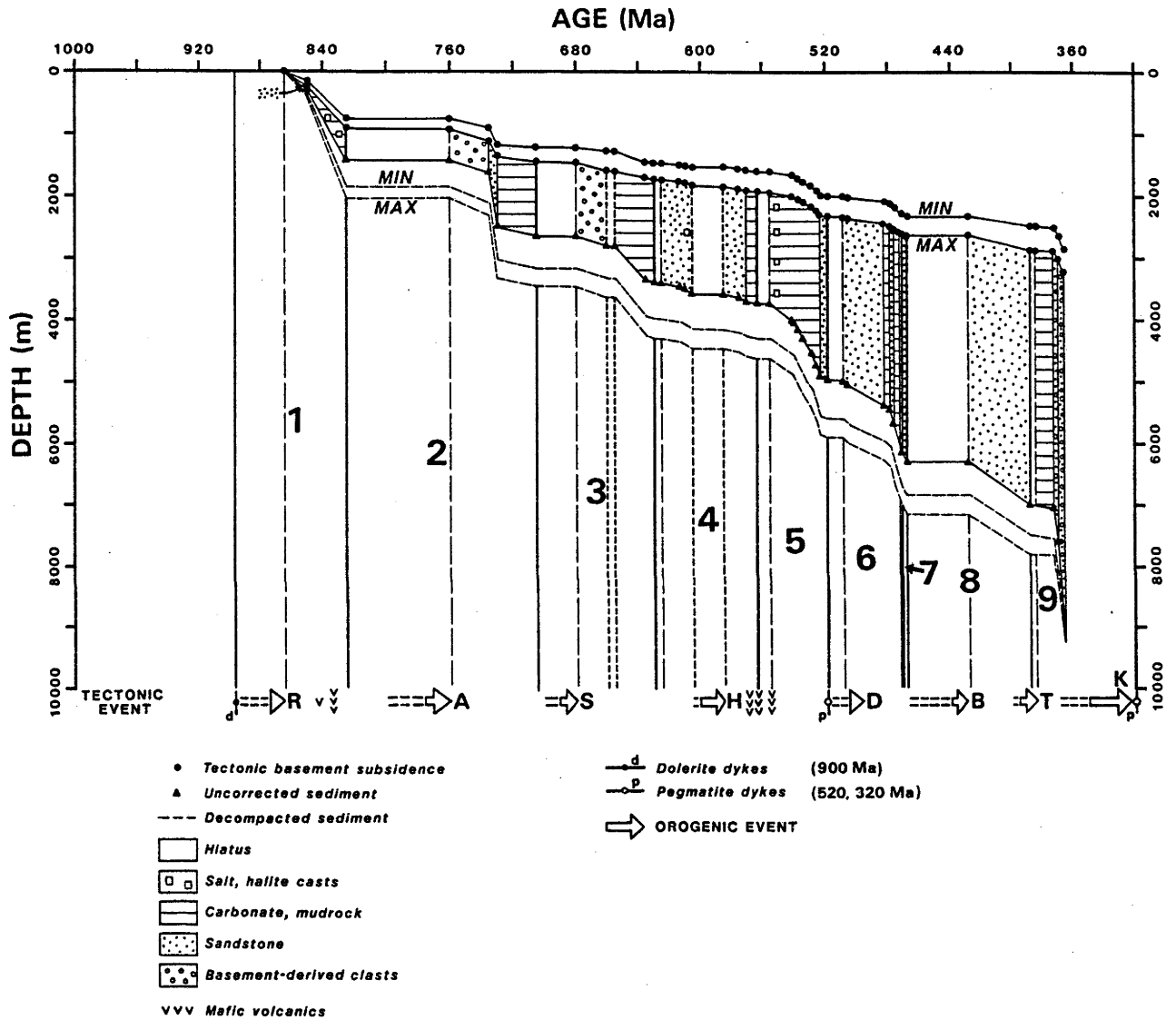


Figure 4-4. Comparison of Palaeozoic subsidence curves derived from wells in the Amadeus Basin (WEST WATERHOUSE 1 and ALICE 1) and composite subsidence curves incorporating outcrop data for the northwestern Ngalia Basin (NGALIA BASIN) and western Georgina Basin (BMR13). Tectonic basement subsidence is shown by two uppermost curves (diagonally crossed lines (-x-)), uncorrected sediment subsidence by the lowest curve (a vertically crossed line (-+-)), and decompacted sediment by a dashed line (---). Erosional unconformities are represented by horizontal lines. Rapid subsidence in the basin starts at about 555 Ma and increased further at about 530-540 Ma, before progressively decreasing. A second period of rapid subsidence at about 480 Ma, documented in West Waterhouse 1, is poorly constrained in time in the Ngalia Basin and the interval was removed by extensive Silurian erosion in the other wells. Rapid subsidence recommenced in the Late Devonian. Late Cambrian and Silurian erosion was most extensive in the Ngalia Basin. Subsequent uplift to the surface assumes that the preserved thickness equals the deposited thickness. Consequently, the full Late Devonian-Carboniferous subsidence is not represented, especially in Alice 1. The subsidence curves assume Airy isostatic condition and that deposited sediment displaces pre-existing sea water. Consequently, the tectonic basement subsidence may be underestimated. The curve for West Waterhouse 1 starts at 506 Ma with sequence 6. The other curves start with sequence 5 at about 585 Ma.

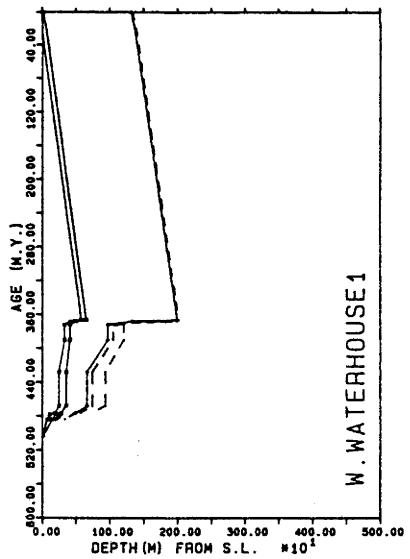
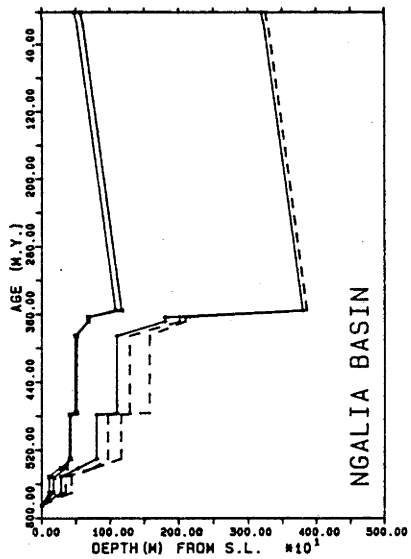
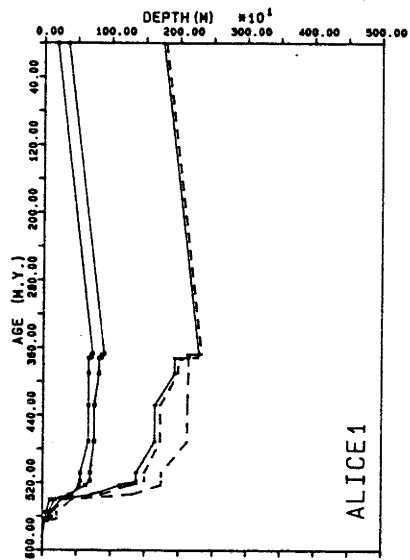
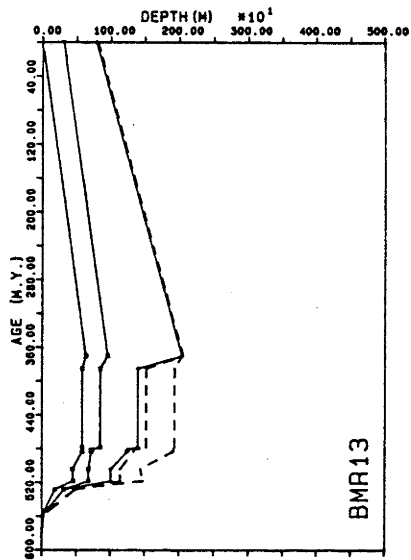


Figure: 4-5. Location of wells in the Amadeus Basin. 1 = Mereenie 1, East Mereenie (oil/gas); 2 = Palm Valley 1 (gas/condensate); 3 = Dingo 1 (gas); 4 = Ooraminna 1 (gas); 5 = Alice 1 (oil); 6 = East Johnny Creek 1 (oil/gas); 7 = West Walker 1 (gas); 8 = Lake Amadeus 1 (oil); 9 = Gosse Bluff 1 (gas); 10 = Orange 1 (gas); 11 = West Waterhouse 1, 12 = Tyler 1; 13 = Mount Winter 1 (oil); 15 = Tempe Vale 1 (oil); 16 = Finke 1 (gas); 17 = Tent Hill 1 (gas). In addition Wallaby 1 (gas) lies northeast of Alice 1 and Rodinga 1 (oil) lies east northeast of Ooraminna 1.

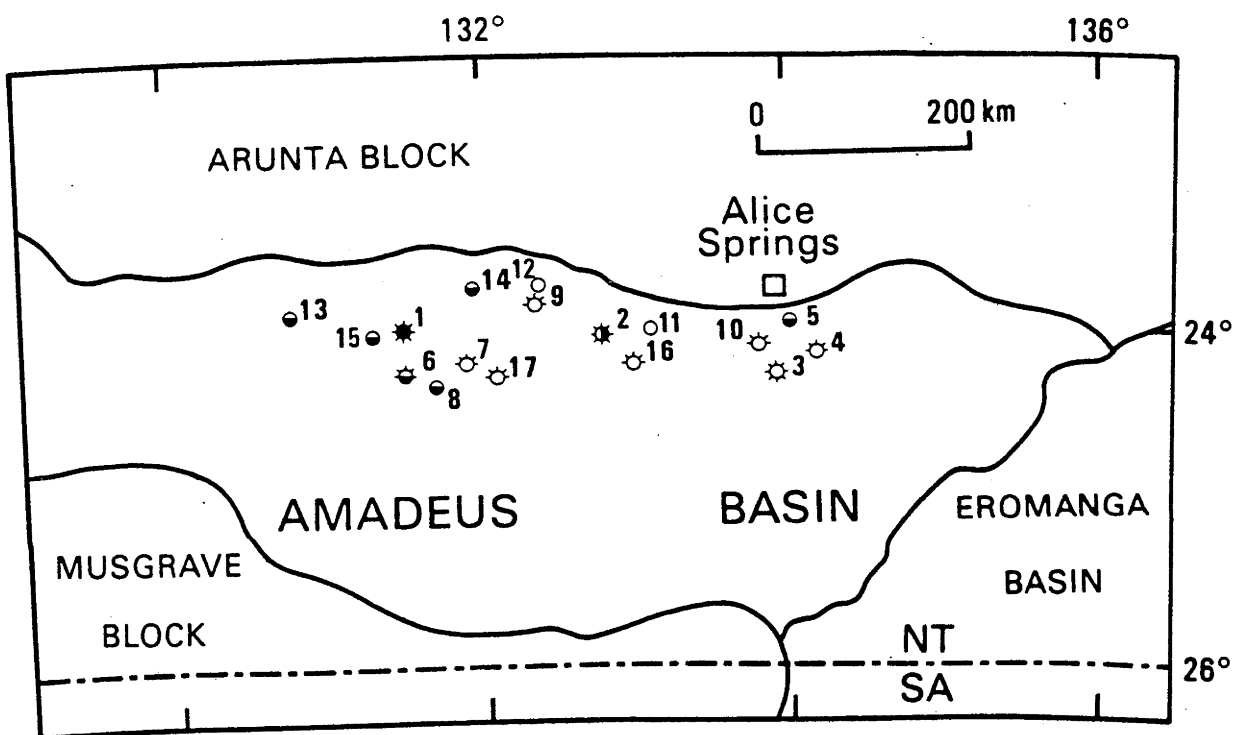


Figure: 4-6. A schematic, composite stratigraphic sequence for the northern Amadeus Basin. The composite section is based on intersections in the Tyler 1, West Waterhouse 1, Dingo 1 and Ooraminna 1 Wells (Fig. 4-5). Missing parts of the section are filled in from field sections. These are the section below the salt horizon in sequence 1 and the insert for sequences 2 and 3 (Wells et al, 1967; Shaw et al, 1982). Stratigraphic units are: B = Brewer Conglomerate, H = Hermannsburg Sandstone, P = Parke Siltstone, M = Mereenie Sandstone, C = Carmichael Sandstone, S = Stokes Siltstone, R = Stairway Sandstone, V = Horn Valley Siltstone, F = Pacoota Sandstone, G = Goyder Formation, N = Shannon Formation, U = Hugh River Shale, K = Giles Creek Dolomite, D = Chandler Formation, T = Todd River Dolomite, A = Arumbera Sandstone 3 & 4, Z = Arumbera Sandstone 1 & 2, J = Julie Formation, E = Pertatataka Formation, O = Olympic Formation, L = Aralka Formation, Y = Areyonga Formation, I = Bitter Springs Formation, Q = Heavitree Quartzite.

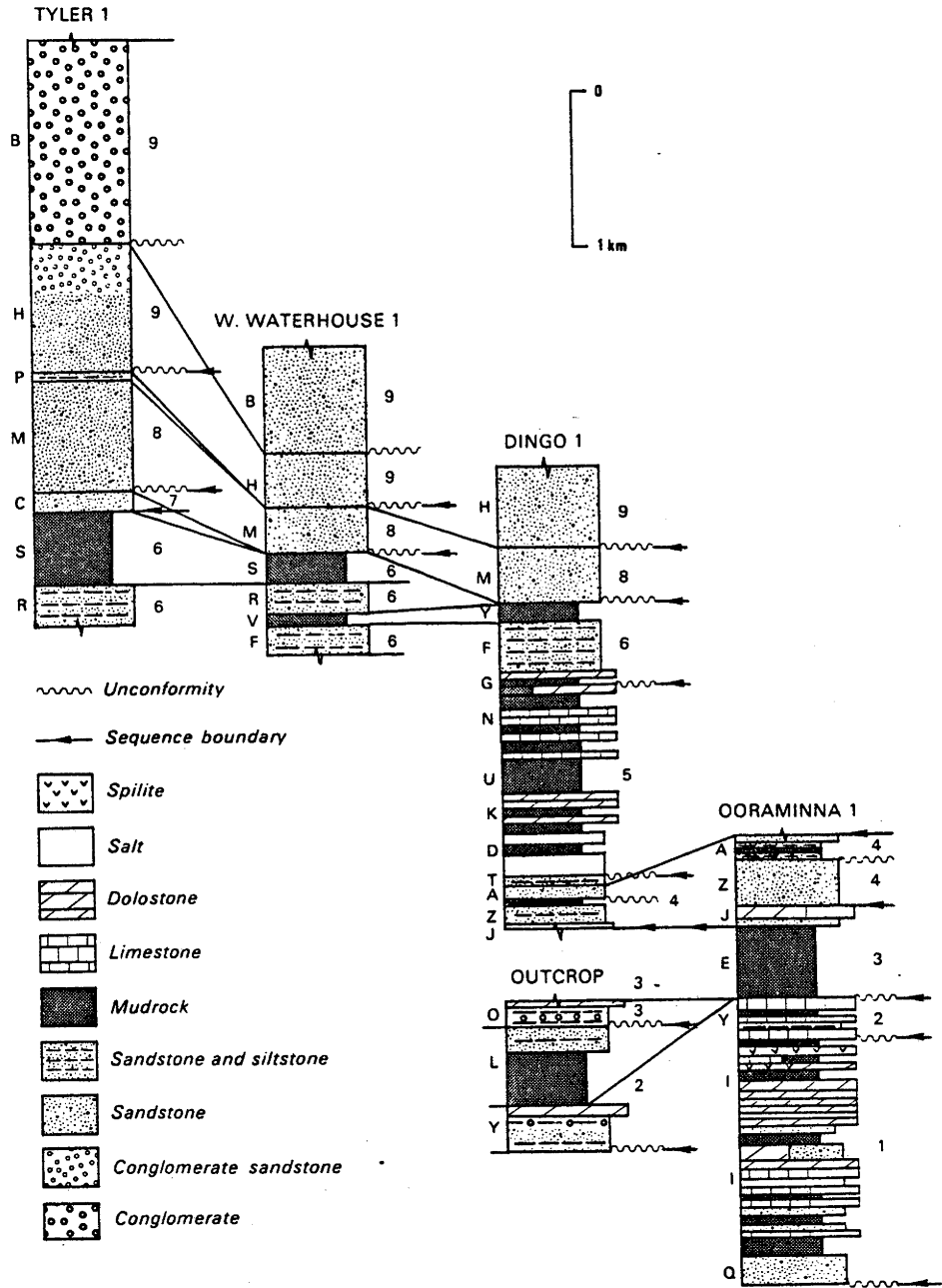
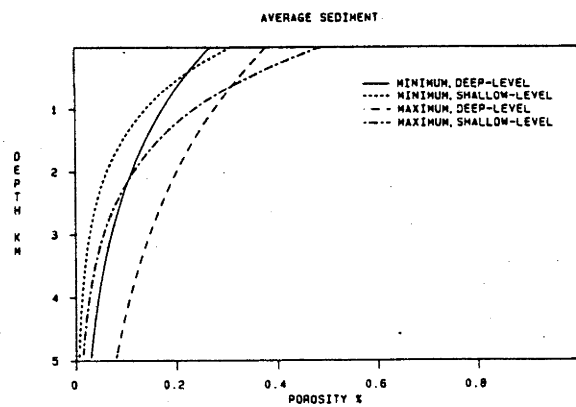
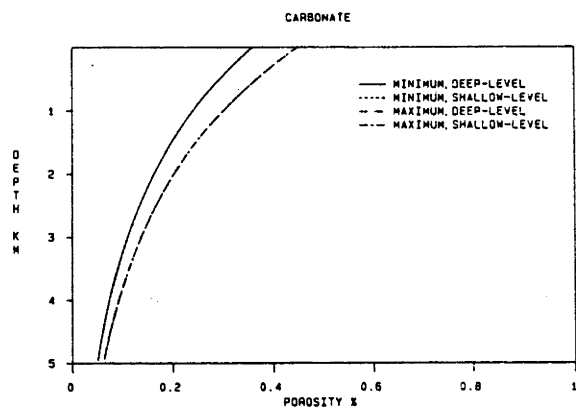
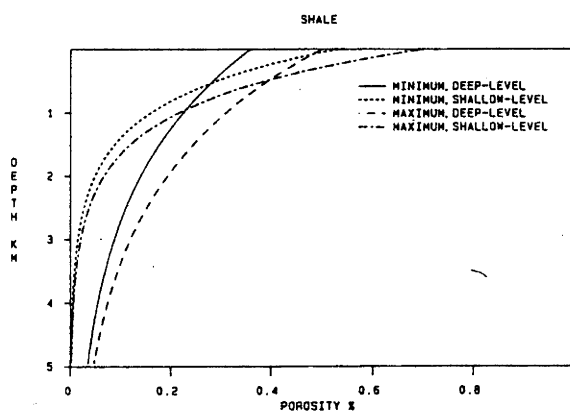
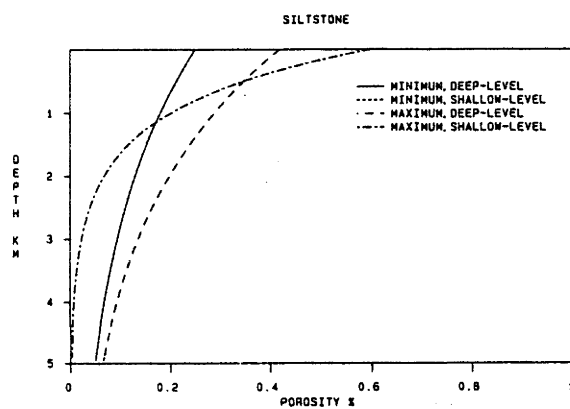
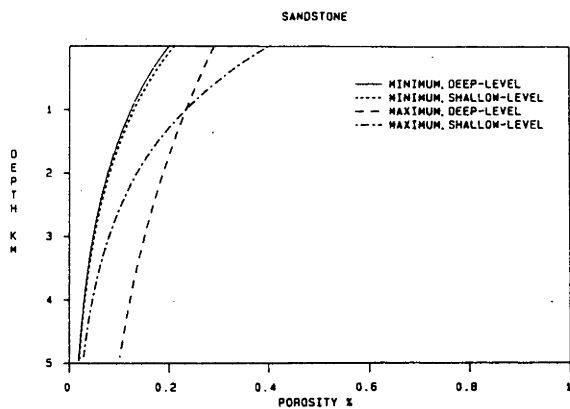


Figure 4-7. Generalised porosity-depth curves adopted in estimating basement subsidence.



COMPOSITE REFERENCE FOR DEPOSITIONAL
INTERVALS IN CENTRAL AUSTRALIA

Figure: 4-8. Basin shapes in central Australia during the glacial depositional intervals 2 and 3 (about 825-705 Ma (sequence 2), and 705-605 Ma (sequence 3)). The composite reference applies to basin reconstruction for all the depositional intervals in central Australia. Inserts show main depocentres (see text for discussion).

3. Upper Glaciogenic interval (Marinoan glacial period): Pertatataka Formation, Julie Formation, Pioneer Sandstone, Olympic Formation (sub-basins 3B and 3C, northern Amadeus Basin); Winnall beds (sub-basin 3A, southern Amadeus Basin); Sir Frederick Conglomerate, Ellis Sandstone, Maurice Formation (western Amadeus Basin); Mount Doreen Formation (Ngalia Basin NB); Keepera and Mopunga Groups (sub-basins KT and AT, Georgina Basin). Tilloids, conglomerate, arkose = closed triangles

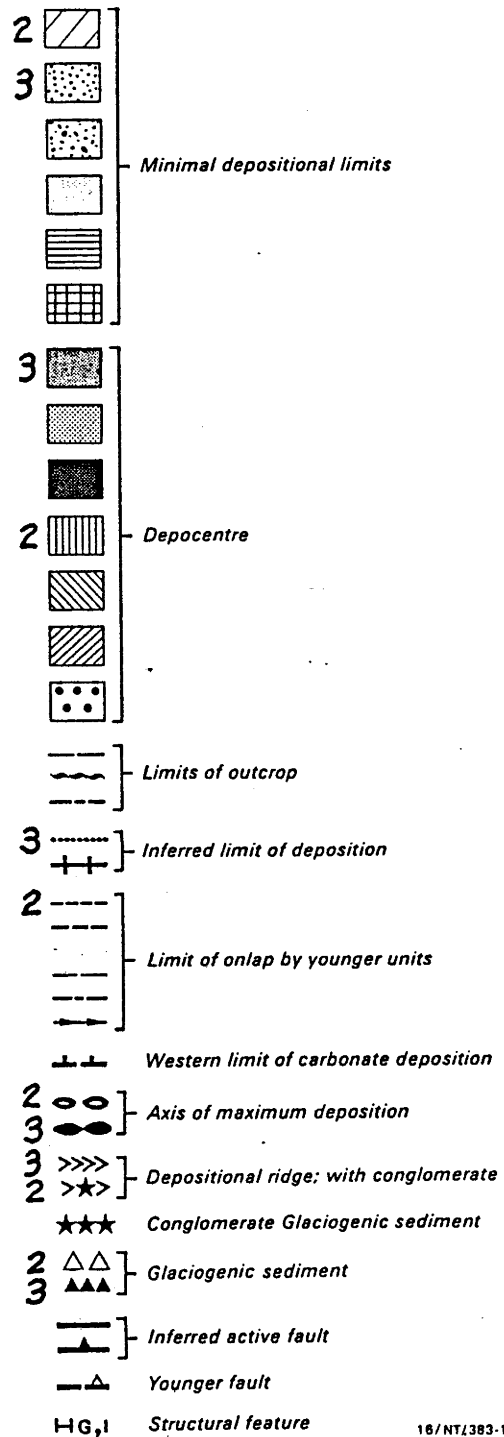
Depositional ridge = right barbs; depocentres = heavy stipple with thick-dashed border

2. Lower Glaciogenic interval (Sturtian glacial period): Areyonga Formation, Aralka Formation (sub-basins 2B and 2C, northern Amadeus Basin); Inindia beds (sub-basin 2A, southern Amadeus Basin); Boord Formation, Carnegie Formation (western Amadeus Basin); Naburula Formation (Ngalia Basin); Mount Cornish Formation and equivalent small en-echelon sub-basins, Yardida Tillite (sub-basin AT, Georgina Basin); Tilloids and conglomerate = open triangle; Depositional ridge = left barbs; Inferred overlap of Areyonga Formation by upper glaciogenic unit (3) = short dashed line; depocentres = heavy stipple with thick dashed border.

Tectonic Features : AT = Adam Trough, KT = Keepera Trough

WB = Walabanba Fault Zone, RZ = Redbank Deformed Zone, SF = Sir Frederick Fault, PN = Petermann Ranges Nappe, WF = Woodroffe Thrust, BF = Black Hills Fault. GT = Gardiner Fault

References : Shaw et al, 1984 ; Shaw and Freeman, 1987 Tucker et al, 1979; Walter, 1981 ; Wells et al, 1970.



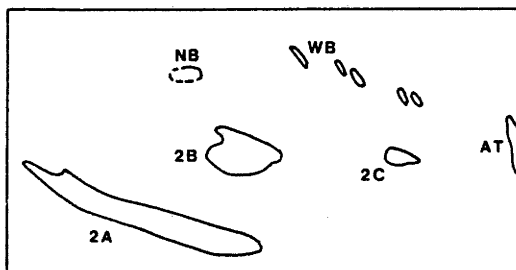
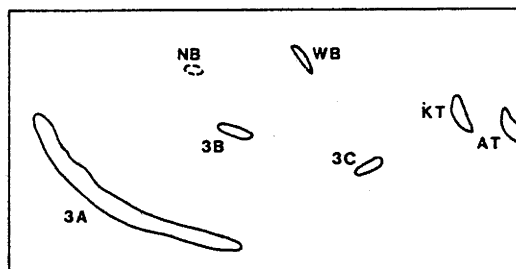
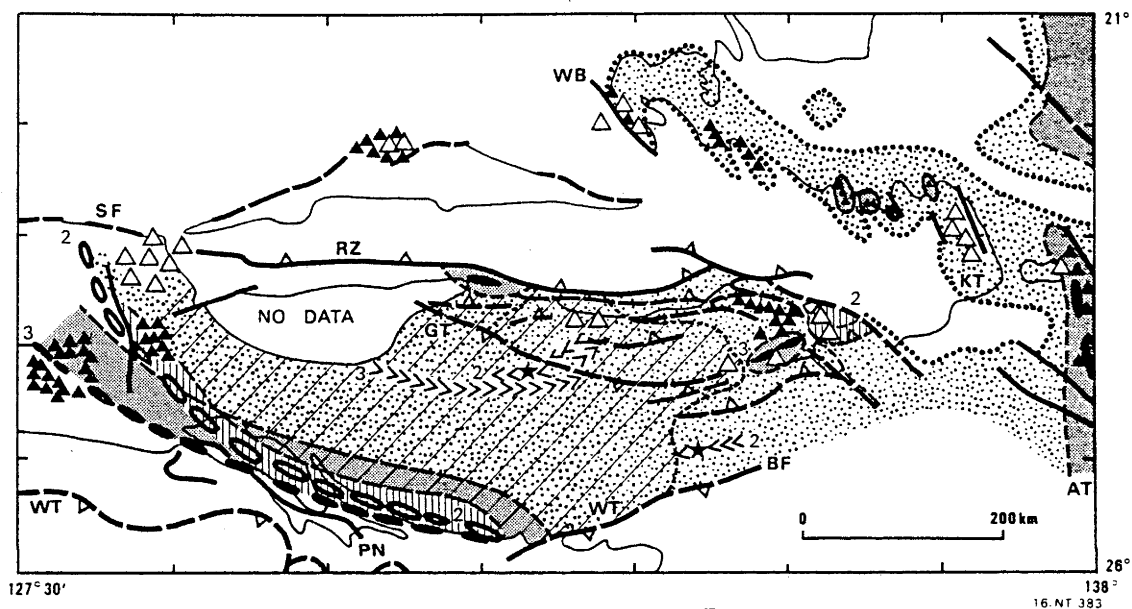


Figure: 4-9. Basin shapes in central Australia for the depositional intervals 4 and 5 (about 630 Ma to about 520 Ma i.e. latest Proterozoic to latest Cambrian). Refer to composite reference for general explanation.

(a) Depositional Interval 4

4T,4W,4R. Deposition of youngest unit i.e. Todd River Dolomite and correlates:

Todd River Dolomite (**4T**) overlapped by younger units = barbed line; Walbiri Dolomite - Ngalia Basin (**4W**); Errarra Formation - Georgina Basin (**4R**); Limit of deposition of Chandler Limestone of sequence 5 (**4CD**) = Crossed line.

4A,C,D,E,F,Z. Deposition of oldest unit i.e. Arumbera Sandstone and correlates : **A, Z** - Arumbera Sandstone and Eninta Sandstone , **C** - Yuendumu Sandstone , **D** - Central Mount Stuart beds , **E** - Mount Baldwin Formation, **F** - Adam Shale (sub-basins A to G, see text).

Arumbera Sandstone overlapped by younger units of the Pertaoorta Group = dotted line (**4A**).

Deposit of Quondong conglomerate = stars

4PR. Deposition of Mount Currie Conglomerate and Ayers Rock Arkose (age uncertain).

Inferred depositional limit (**4PR**); Preserved depositional limit = dotted line

Tectonic Features: as for Figure 4-8, **4WL** = Woolanga

Lineament (— — — —), **CD** = Depositional limit of Chandler Limestone.

References: as for Figure 4-8.

Other Features: **G** = Goyder Pass Structure; **I** = Illamurta Structure, **GS** = Discordant Structure.

(b) Deposition of Interval 5 i.e. most of Pertaoorta Group :

5U. Late Cambrian units of the Georgina Basin - Arrinthrunga Formation (sub-basins D, E and F).

5M. Middle Cambrian units of the Georgina Basin - Arthur Creek Formation; Depositional ridge = barbs (sub-basins F and G).

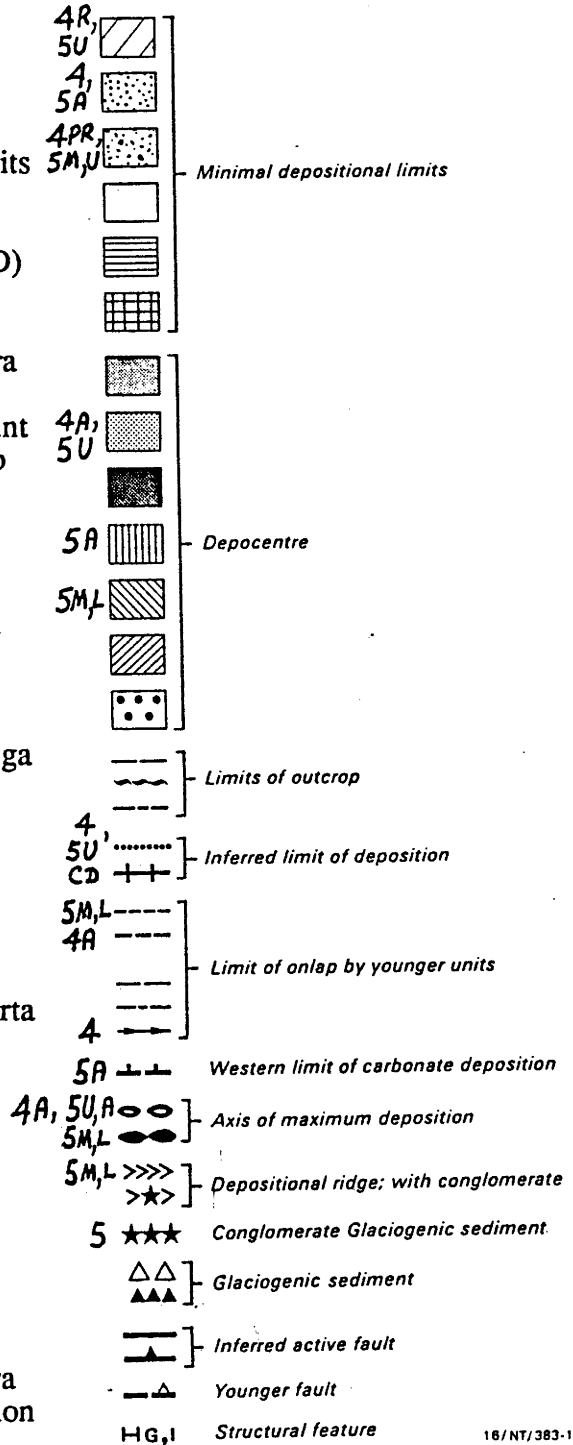
5L. Late Early to early Middle Cambrian unit of the Georgina Basin : Limits of deposition of Andagera Formation (scattered outcrops only) = dot and circle pattern (no distinct sub-basin).

5A. Pertaoorta Group Amadeus Basin (less Arumbera Sandstone and Todd River Dolomite, limit of deposition = dotted line; sub-basins A and B).

5N. Bloodwood Formation (sub-basin C, Ngalia Basin).

Additional features: Western limit of carbonate deposition = ticked line; **G** = Goyder Pass Structure; **I** = Illamurta Structure

COMPOSITE REFERENCE FOR DEPOSITIONAL INTERVALS IN CENTRAL AUSTRALIA



COMPOSITE REFERENCE FOR DEPOSITIONAL
INTERVALS IN CENTRAL AUSTRALIA

Figure: 4-10. Basin shape in central Australia for depositional intervals 6, 7 and 8 (about 520 to 2400 Ma). General explanation is given in composite reference.

(a) Larapinta Group and correlates.

6U. Toko Group (e.g. Nora Formation), Georgina Basin

limit of outcrop = dashed line

6L. Tomahawk beds, Ninmaroo Formation, lower Kelly Creek Formation - Georgina Basin

6N. Djagamara Formation - Ngalia Basin

6F. Pacoota Sandstone - Amadeus Basin

6S. Stairway Sandstone, Stokes Formation - Amadeus Basin

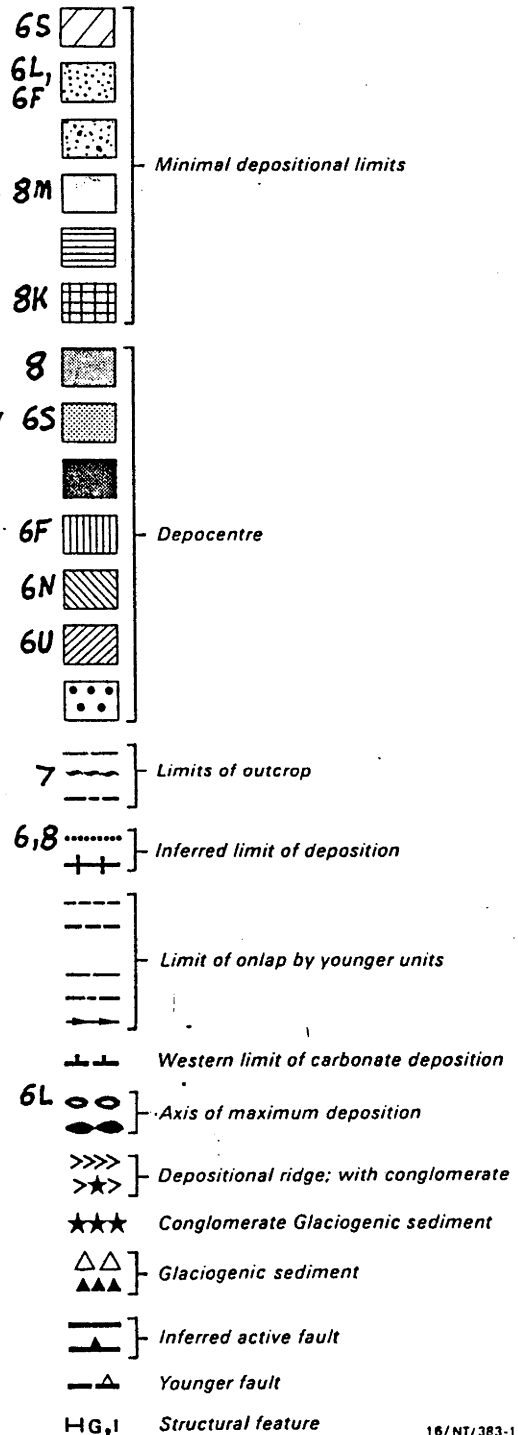
(includes Horn Valley Siltstone). Limit of onlap (i.e. overlap) of Pacoota Sandstone by Stairway Sandstone is shown by a short dashed line (6F).

(b) Carmichael Sandstone, and Mereenie Sandstone and its correlates

7. Carmichael Sandstone - Amadeus Basin (wavy line marks western depositional limit)

8M. Mereenie Sandstone - Amadeus Basin

8K. Kerridy Sandstone - Ngalia Basin



COMPOSITE REFERENCE FOR DEPOSITIONAL
INTERVALS IN CENTRAL AUSTRALIA

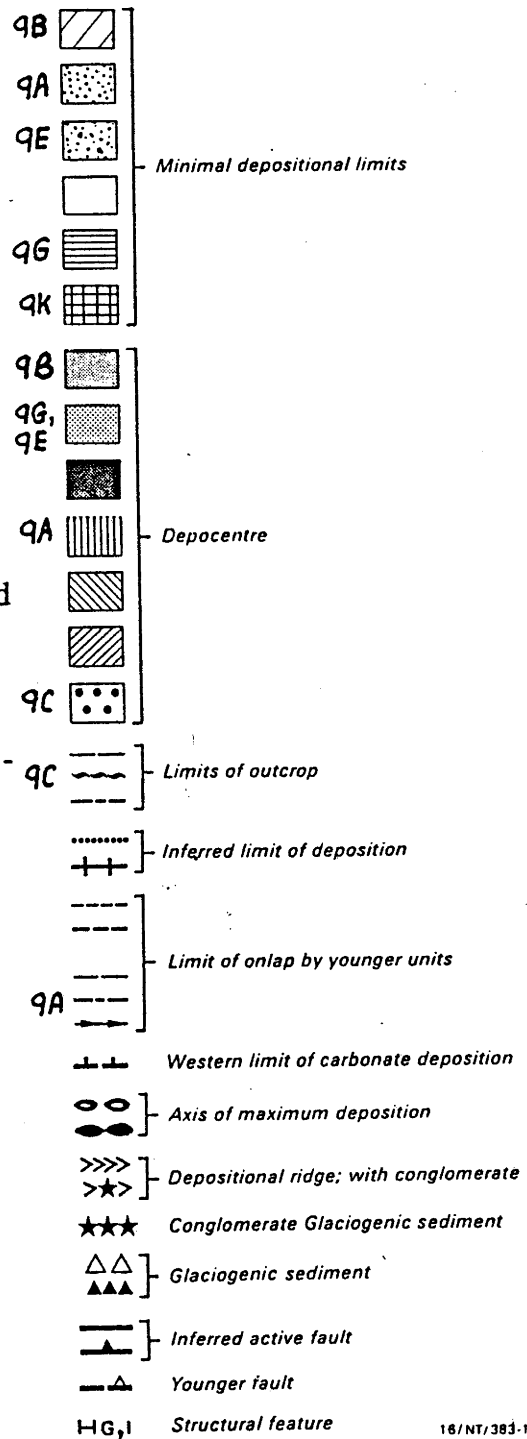
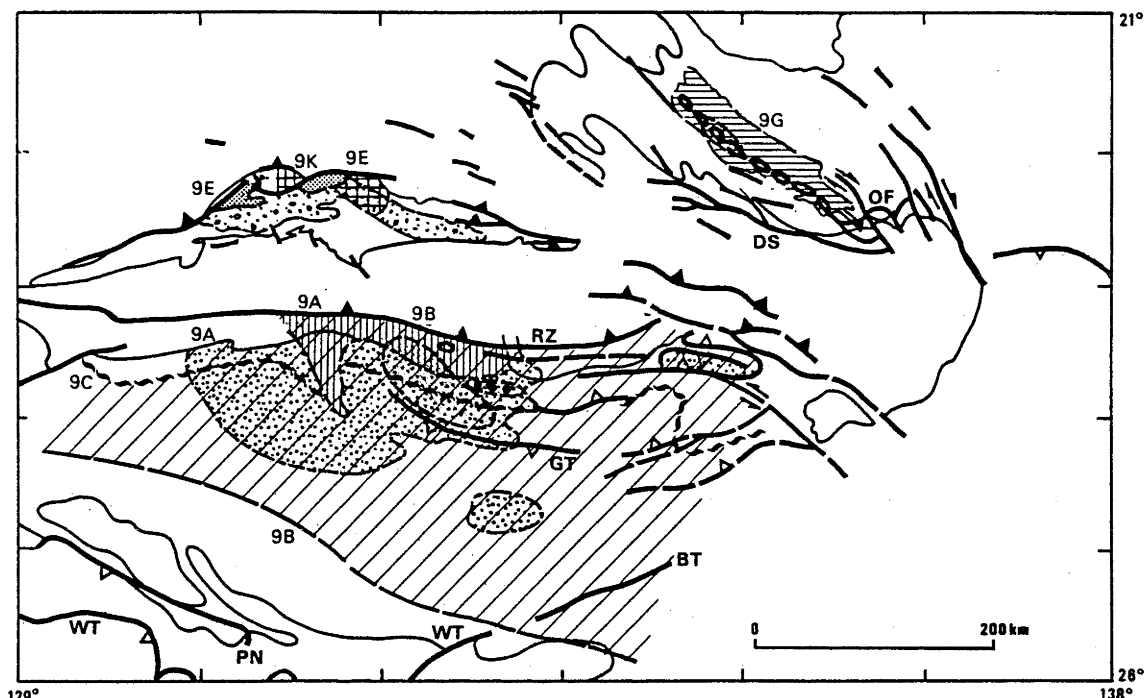


Figure: 4-11. Basin shapes in central Australia for depositional interval 9 (about 460 to 300 Ma). (General explanation given in composite reference).
Pertnjara Group and correlates
9. Pertnjara Group - Amadeus Basin
9A. Parkes Siltstone: limit of depocentre = thick dashed line (sub-basins A1, A2 and A3)
9B. Hermannsburg Sandstone: limit of outcrop = dashed line (sub-basin B1)
9C. Brewer Conglomerate: outcrop limit = wavy line
9G. Dulcie Sandstone - Georgina Basin (sub-basin A5 - B3)
9K. Kerridy Sandstone - Ngalia Basin (sub-basin A4 - B2)
9E. Mount Eclipse Sandstone - Ngalia Basin: limit of depocentre = thick dashed line (sub-basin C2).
Tectonic Features: RZ Redbank Deformed Zone; GT = Gardiner thrust; OF = Oomoomilla Fault; DS = Delny - Mount Sainthill Fault Zone; other features as in Figure 4-8.
References : J.Gorter, Pancontinental Petroleum, pers comm. Jones, 1972, Wells et al, 1970, Wells and Moss, 1983



129°

21°
26°
138°

16/NT/387-1

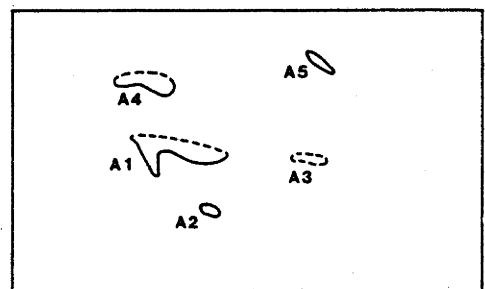
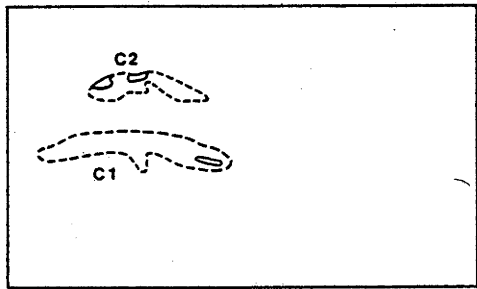
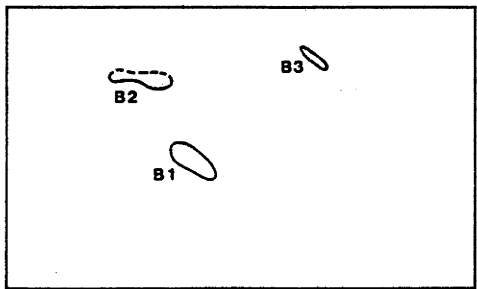
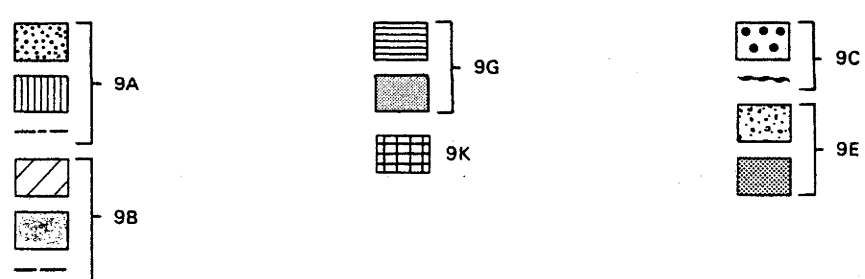


Figure: 4-12. Depositional regions inferred for pre-Amadeus Basin period (roughly 1150-900 Ma) showing a spacial relationship to mid-Proterozoic mobile belts. Gravity Lineaments are outlined by straight lines as follows: A = Angus, L = Lake MacKay, E = Ennugan, W = Woolanga. Tectonic Features: HB = Halls Creek mobile Belt; THZ = Torrenz Hinge Zone; Tasman Line = fine dashed line (inferred edge of Precambrian craton). Geological Feature: Bangemall Basin. References: Daniels (1974), Mathur and Shaw (1982); Plumb et al, 1981; Rutland et al, 1981; Preiss and Forbes (1981); Shaw et al (1984).



Figure 4-13. Paleogeographic sketch map for period 900-825 Ma (approx.) showing broad scale, interpretative isopachs:

a) on the basal quartzite units (comparable to Heavitree Quartzite) outlining regions with greater than 500 m of sediment plus maximum thickness estimates and

b) Inferred regions of maximum deposition for the overlying carbonate and shale-dominated units in the upper part of sequence 1 (comparable to Bitter Springs Formation). Maximum thicknesses are indicated. The distribution of mafic volcanics is also shown (as v's).

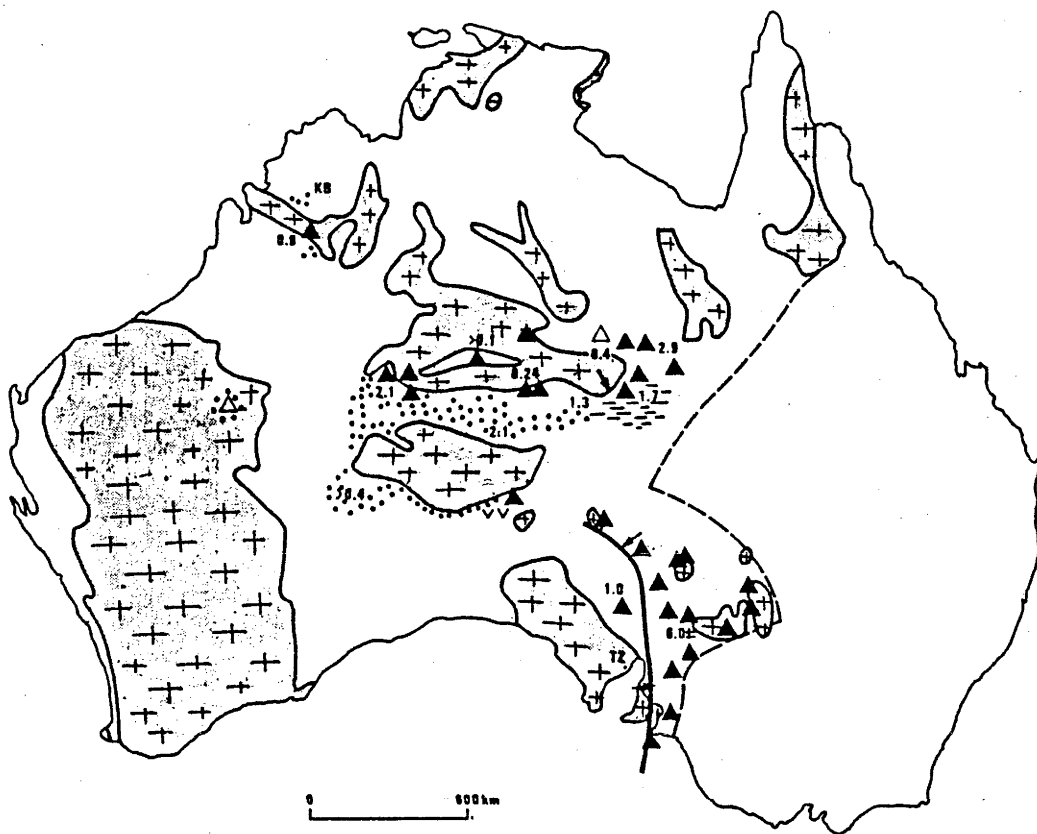
Assumed tectonostratigraphic correlates of Heavitree Quartzite are: Dean Quartzite, Vaughan Springs Quartzite, Townsend Quartzite, lower Lefroy beds, basal quartzites of Burra Group, Yackah beds, Denison beds, Lewis Range Sandstone, Muriel Range Sandstone, Munya Sandstone. Tectonostratigraphic correlates of the Bitter Springs Formation are as in Figure 4-1.

Inferred active tectonic features are: T = Torrens Hinge Zone, W = Woolanga Gravity Lineament, E = Ennugan Gravity Lineament, L = Lake MacKay Gravity Lineament, A = Angus Gravity Lineament.

References: Blake et al, 1979; Clarke, 1976; Daniels, 1974; Jackson & Van de Graaff, 1981; Major 1973b; Preiss & Forbes, 1981; Shaw et al, 1971; Shaw et al, 1982; Rutland et al, 1981; Walter et al, 1979; Wells et al, 1970; Wells & Moss, 1983.



Figure 4-14. Distribution and dominant facies for Late Proterozoic sedimentation for the period 825-705 Ma (Sturtian glacial period). References: Preiss & Forbes, 1981; Preiss et al, 1978; Wells et al, 1970; Walter et al, 1979; Shaw et al, 1982; Jackson and Van de Graaff, 1981.



825-705 Ma

▲ Glaciols

△ Arkose

⬢ Sandstone

⬢ Shale

▼ Basalt

➤ Source area (inferred)

1.0 Thickness (km)

⬢ Archaean and Proterozoic basement.
(presently exposed)

--- Tasman line

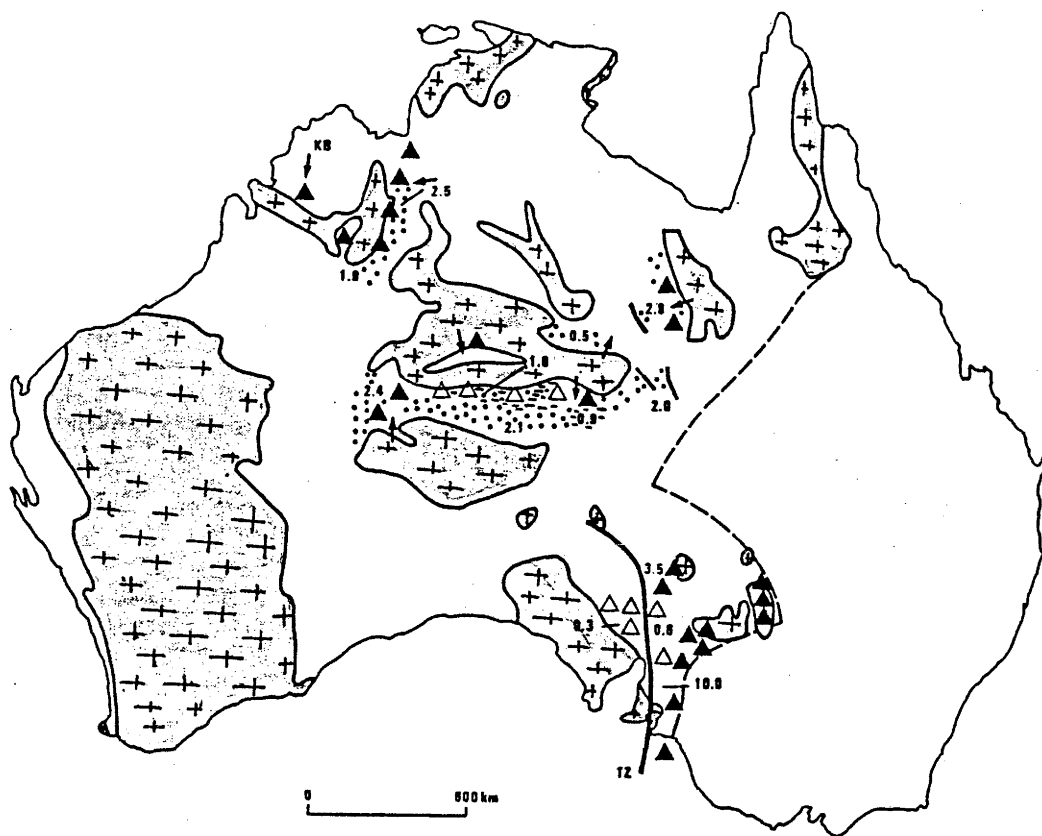
TZ Torrens Hinge Zone

KB Kimberley Block

— Fault

18/A/108

Figure: 4-15. Distribution and dominant facies of Late Proterozoic sedimentation for the period 705-605 Ma (Marinoan glacial period). References: Preiss & Forbes, 1981, Preiss et al 1978, Wells et al, 1970, Walter et al, 1979, Shaw et al, 1982.



705-630 Ma

▲ Glacials

△ Arkose

■ Sandstone

■ Shale

➤ Source area (inferred)

1.8 Thickness (km)

■ Archaean and Proterozoic basement.
(presently exposed)

--- Tasman line

TZ Torrenz Hinge Zone

KB Kimberley Block

— Fault

18/A/109

Figure: 4-16. The evolving Australian-wide pattern of sedimentation and emergence in the Early and Middle Cambrian; (i) Earliest Cambrian, (ii) Late Early Cambrian, (iii) Earliest Middle Cambrian, (iv) Mid-Cambrian (see text for details). Principal references: Shergold et al, 1985; Gatehouse, 1986; Morris et al, 1986; Crawford et al, 1984; Rutland et al, 1981; Parker, 1986; Wells and Moss, 1983; Cas, 1983; Murray, 1986.



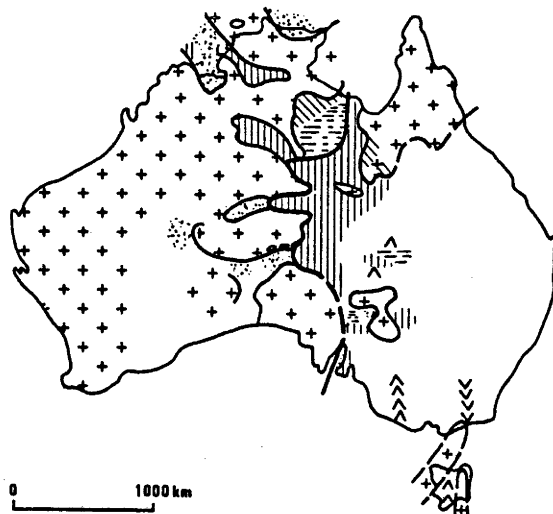
(i) Earliest CAMBRIAN (~ TOMMOTIAN)



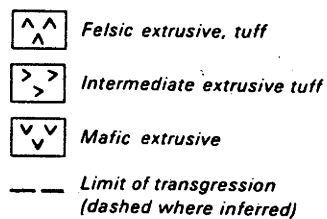
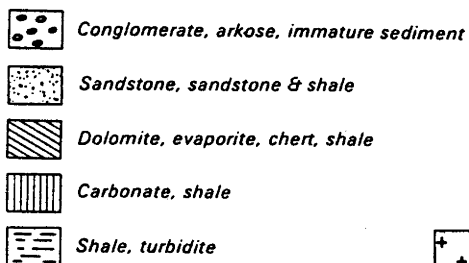
(ii) Early -CAMBRIAN (~ ATDABANIAN)



(iii) Earliest MIDDLE CAMBRIAN (~ ORDIAN)

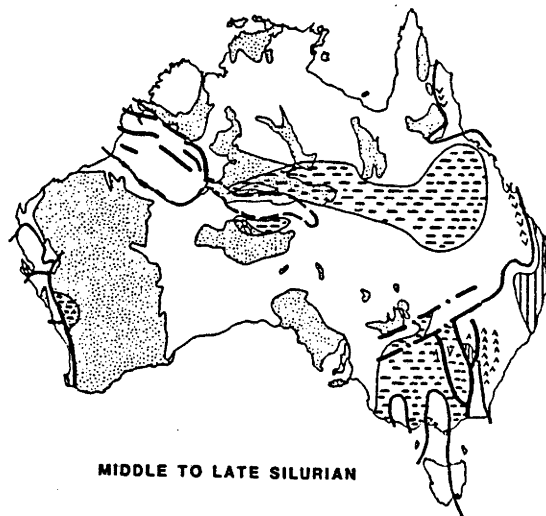
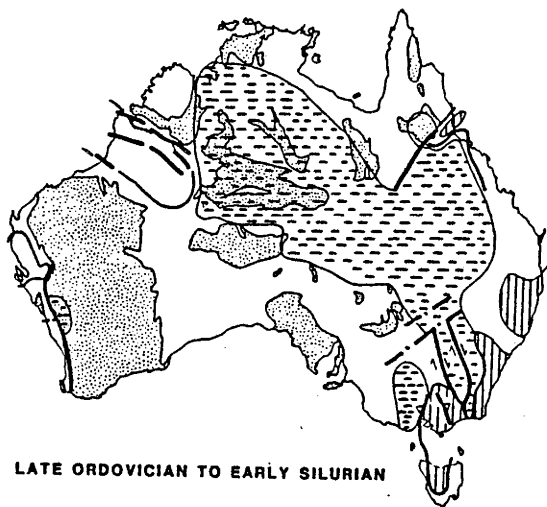
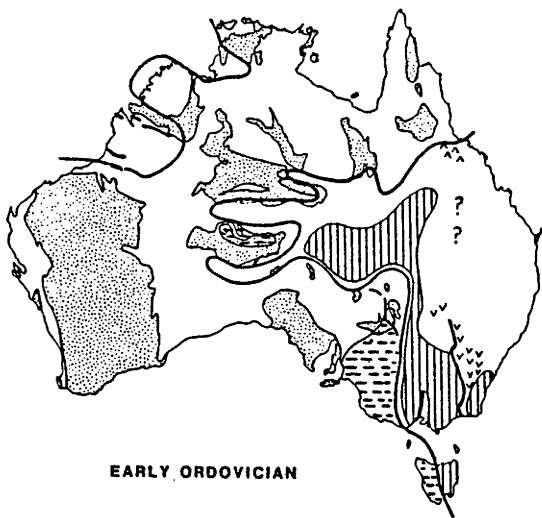


(iv) Mid-CAMBRIAN (~ TEMPLETONIAN - IDAMEAN)



0 1000 km

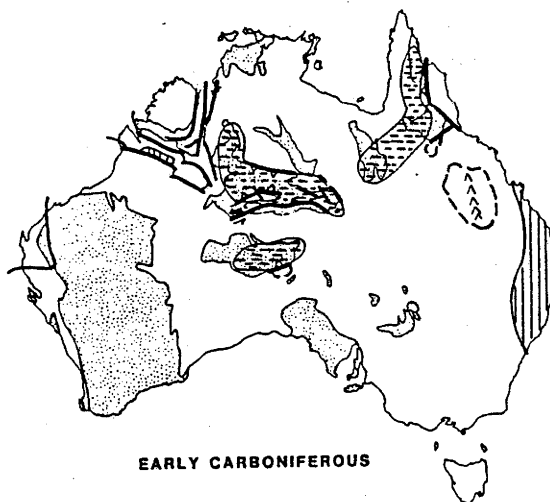
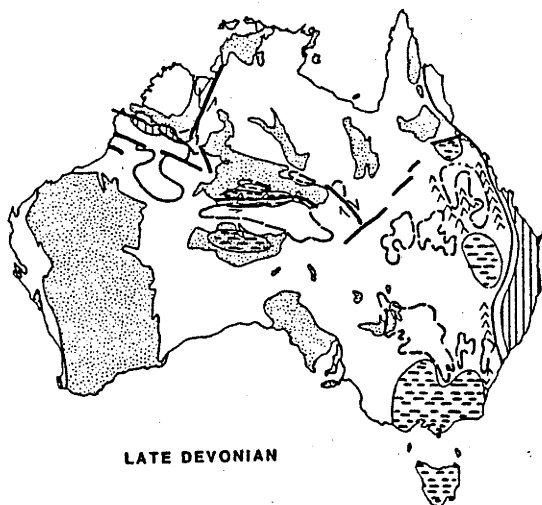
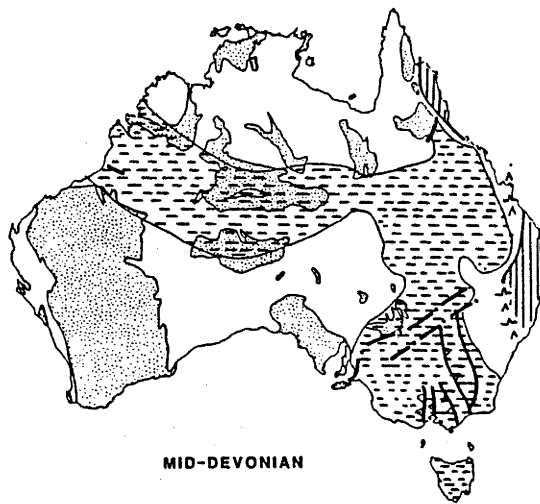
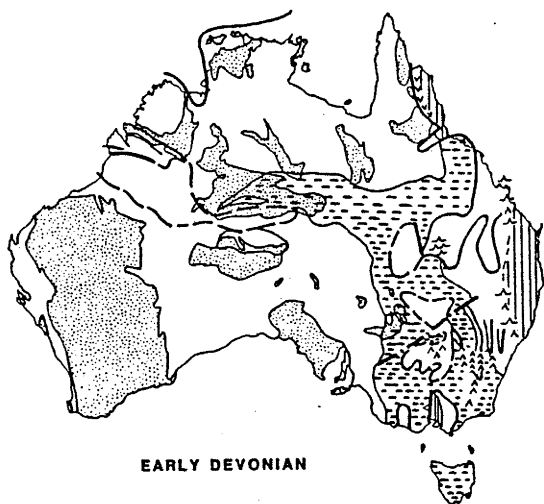
Figure 4-17: Evolving Australia-wide patterns of sedimentation and emergence for the period from Early Ordovician to Late Silurian. (i) Early Ordovician, (ii) Mid-Ordovician, (iii) Late Ordovician to Early Silurian, (iv) Middle to Late Silurian. Present-day Precambrian basement areas (fine dots) are also shown to provide a reference framework. Unclassified areas with no pattern correspond mainly to land. Tectonic Features: WA = Willowran sub-basin (ii), T = Tumut Trough (iv), G = Gilmore Suture (iv), M = Melbourne Trough (iv). Principal References: Cas, 1983; Scheibner, 1983; Powell, 1983; Cox et al, 1983; Cooper and Grindley, 1982; Degeling et al, 1986; Moore, 1982; Forman and Wales, 1981; Murray, 1986; Ramsay and Vandenberg, 1986; Gatehouse, 1986; Smith, 1984; Kennard and Nicholl, 1986; Webby et al, 1981; Wells and Moss, 1983; Wells et al, 1970.



- Limit of marine transgression
- ▨ Deeper-water marine facies
- - - Limit of terrestrial sedimentation
- ▤ Emergent

- △ Felsic volcanics
- ▽ Mafic to intermediate volcanics
- Inferred active fault
- - - - Zone of decoupling

Figure: 4-18. Evolving Australia-wide patterns of sedimentation and emergence for the period from Early Devonian to Early Carboniferous. (i) Early Devonian, (ii) Mid-Devonian (about 380-390 Ma), (iii) Late Devonian, (iv) Early Carboniferous. Tectonic Features: C = Calliope Volcanic Arc, A = Connors-Auburn Arc. Principal References: Jones, 1972; Degeling et al, 1986; Murray, 1986; Murray et al, 1987; Shaw et al, 1987; Powell et al, 1977; Wopfner, 1969; Playford et al, 1975. Present-day Precambrian basement areas (fine dots) are shown for reference. Unclassified areas with no pattern correspond mainly to land.



- Limit of marine transgression
- ▨ Deeper-water marine facies
- - - Limit of terrestrial sedimentation
- ▤ Emergent

- △ Felsic volcanics
- ⌒ Andesitic volcanics
- ▽ Mafic to intermediate volcanics
- Inferred active fault
- · - · - Zone of decoupling

CHAPTER 5

MODELS FOR BASIN FORMATION IN CENTRAL AUSTRALIA

Figure 5-1(A). Schematic S-N section showing the changing basin shape along latitude 133°E.

Schematic S-N section for sequences 1 to 8 in the Amadeus Basin. Sequences are referenced as in Figures 4-6 and 4-3. Sequence thicknesses are uncompacted. Arrows indicate sense of transgression. Dashed lines are inferred and assume no faulting across the Redbank Deformed Zone (RDZ). Dotted lines show the correlation between basins (see text for discussion). Tectonic features: BHF Blackhills Fault, AH Amadeus Homocline, RD Redbank Deformed Zone.

Figure 5-1 (B) Schematic S-N section for sequence 9 along latitude 133°E. Sequences are referenced as in Figures 4-6, and 4-3. 9HL refers to Ljiltera Member of Hermannsburg Sandstone (conglomeratic upper member). Tectonic features: SA Seymour Range Anticline (in older units), JA James Range Anticline, AH Amadeus Homocline.

Figure 5-1 (C). Schematic section of the Georgina Basin extending WE from 135°30'N, 22°43'S to 136°30'E, 22°31'S. Sequences are numbered as in Figures 4-8 and 4-9 (a) and (b). Stratigraphic units are: 2 = Mount Cornish Formation, 3L = Keepera Group, 3U = Mopunga Group, 4E = Mount Baldwin Formation, 4R = Errarra Formation, 5M = Arthur Creek Formation, 5U = Arrintheta Formation, EM = Eurowie Sandstone Member of Arrintheta Formation (sequence 5U). Features are: MR Mopunga Range, CF Charlotte Fault Zone, JR Johannsen Range, BF Bonya Fault, LF Lucy Fault Zone.

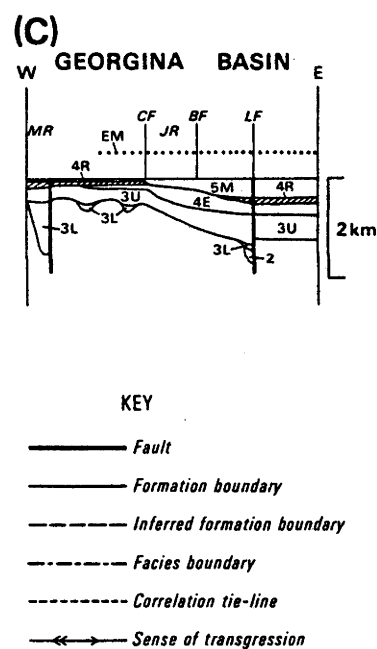
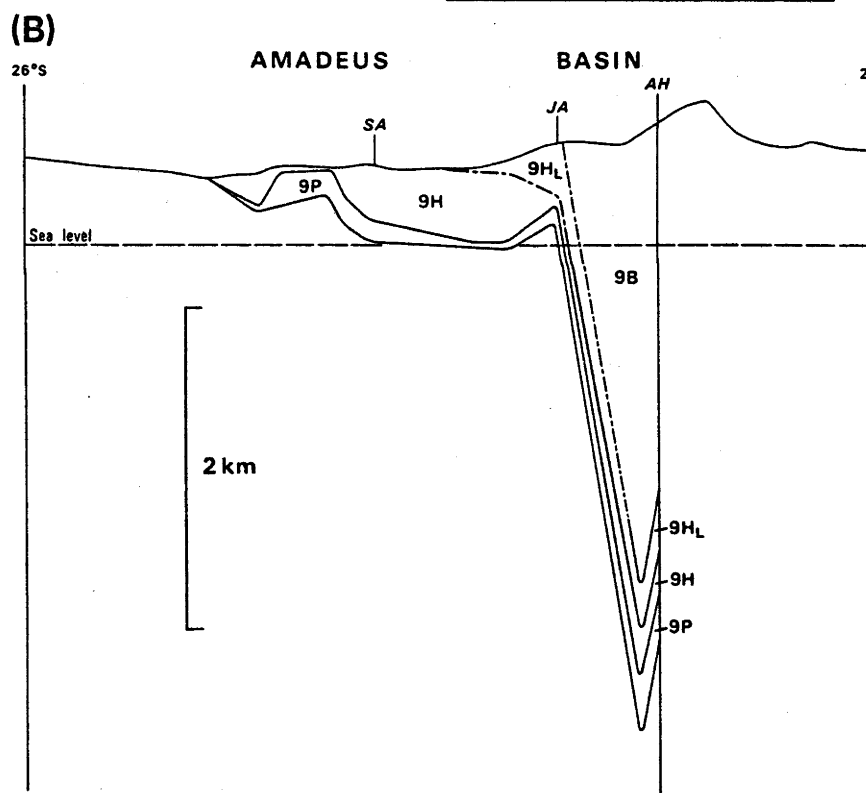
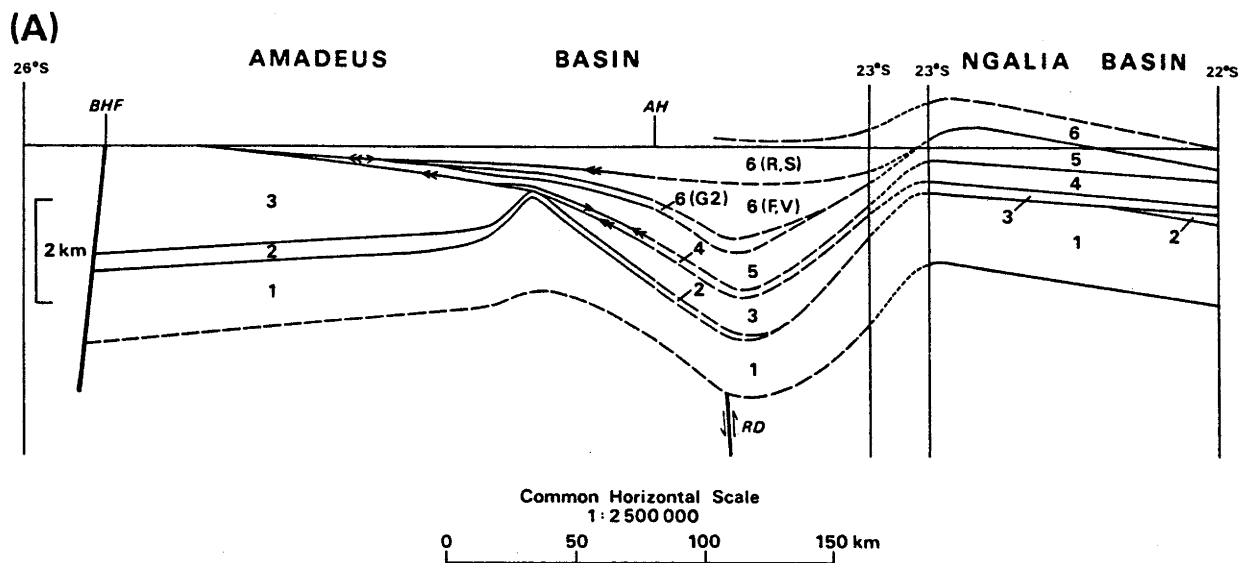


Figure: 5-2. A plot summarising the changing half-width of the Amadeus Basin throughout the life of the basin (RHS y-axis). Also shown are estimates of the effective elastic thickness (HS y-axis) of the lithosphere assuming the simple flexure and line-load models portrayed in Figure 5-4 and adopting flexural parameters given in Table 4-6. The broken lithospheric plate configuration is appropriate for thick-skinned fault models which penetrate to the mantle. The unbroken lithospheric plate model is appropriate for foreland loading models.

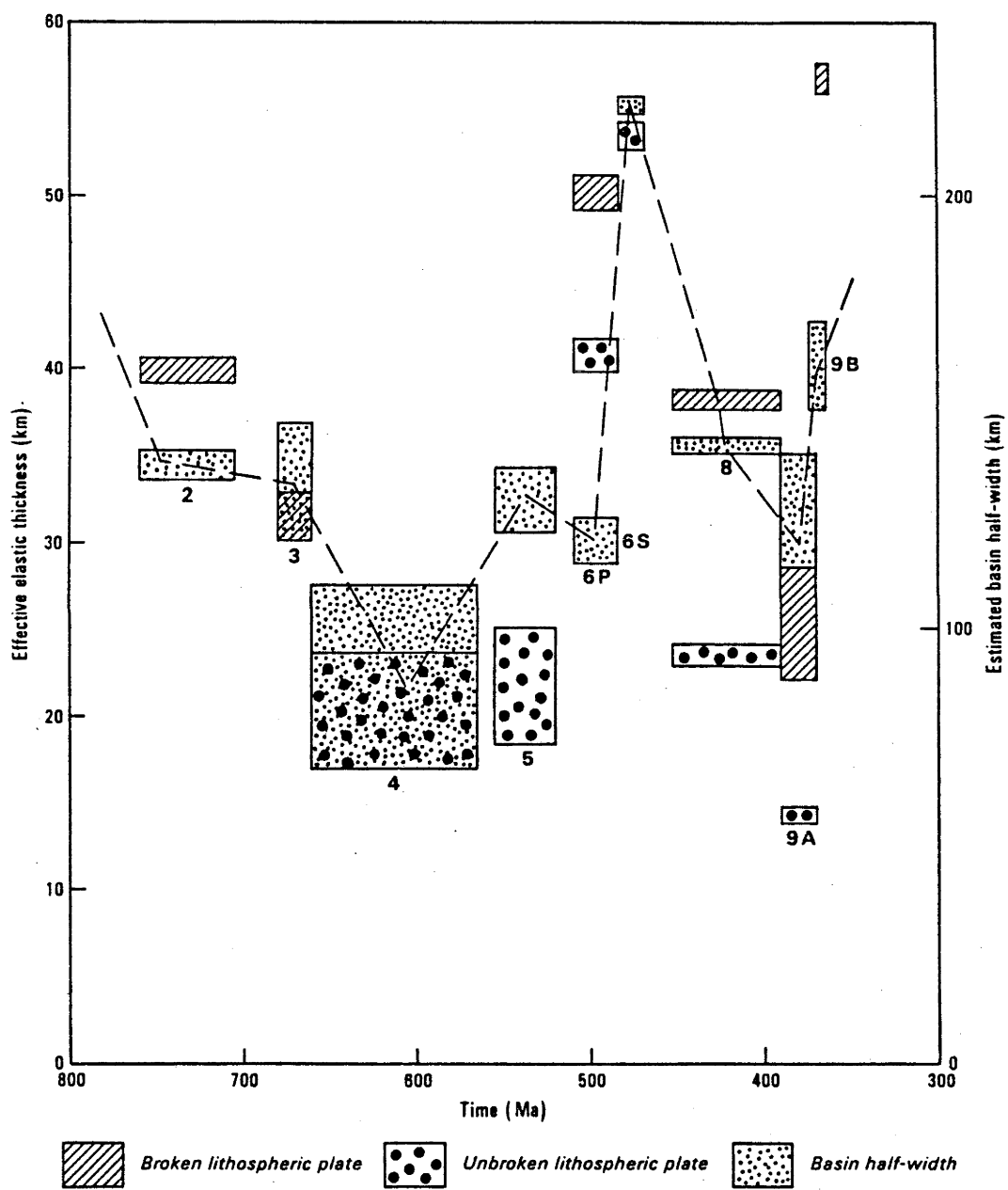
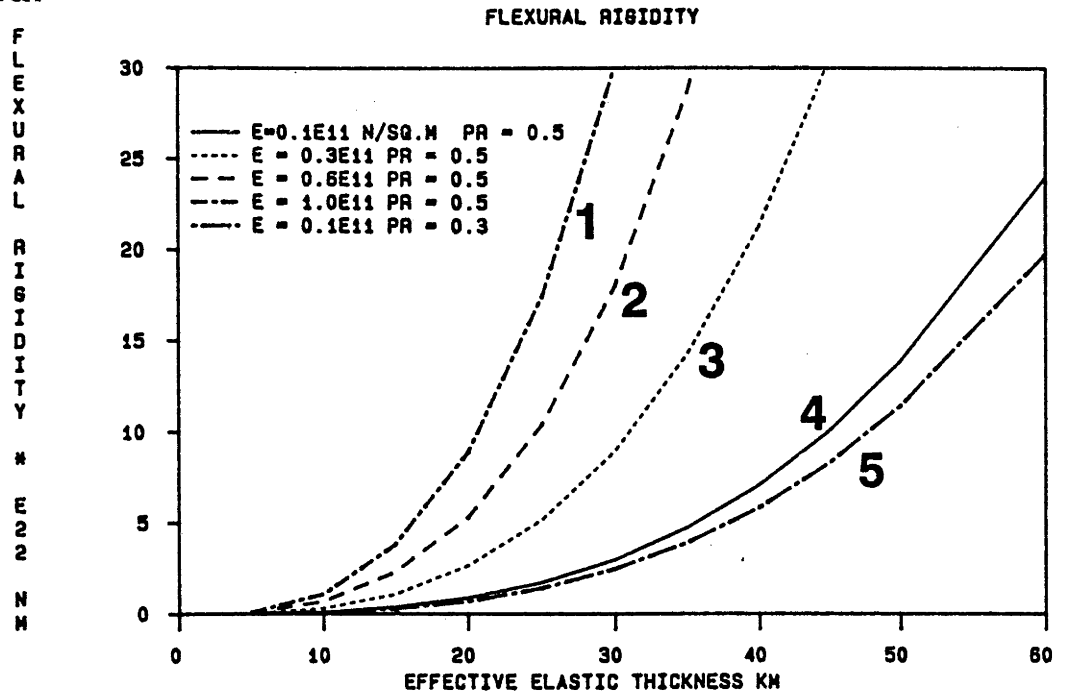


Figure 5-3. The relationship of effective elastic thickness (H) to: (a) Flexural Rigidity (D) and (b) the Flexural Parameter (α).

The values adopted for the curves are:

- (1) Elasticity = $0.3\text{E}11 \text{ Nm}^{-2}$, Poisson's Ratio = 0.5, Buoyancy Force = 33240 Nm (in air)
- (2) Elasticity = $0.3\text{E}11 \text{ Nm}^{-2}$, Poisson's Ratio = 0.5, Buoyancy Force = 22540 Nm (below sea level)
- (3) Elasticity = $0.6\text{E}11 \text{ Nm}^{-2}$, Poisson's Ratio = 0.5, Buoyancy Force = 33240 Nm (as above)
- (4) Elasticity = $1.0\text{E}11 \text{ Nm}^{-2}$, Poisson's Ratio = 0.3, Buoyancy Force = 33240 Nm (as above)

(a)



(b)

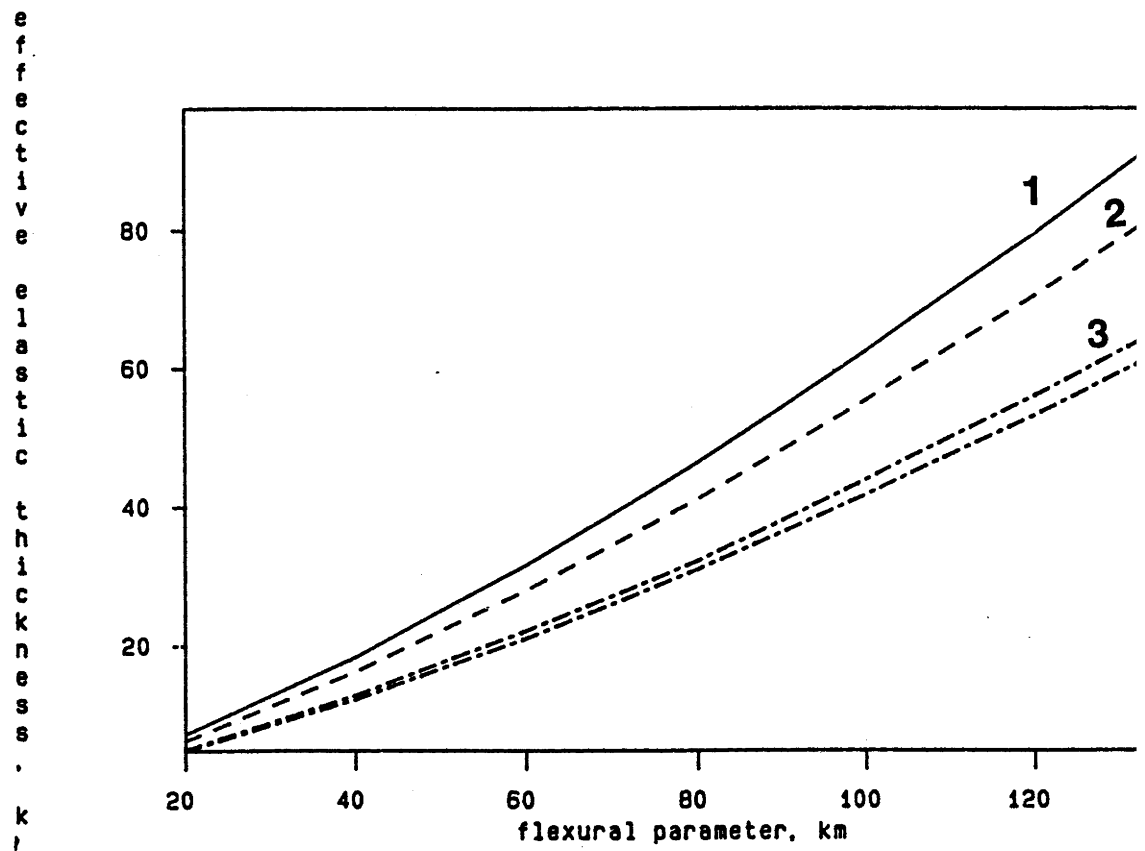
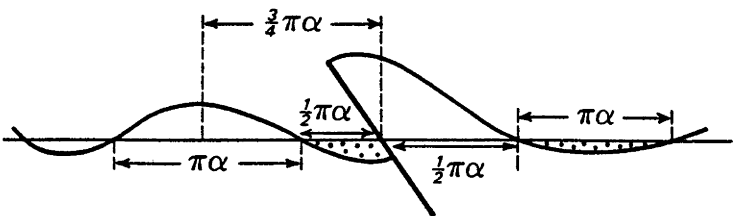


Figure 5-4. Lithospheric flexure as a function of the flexural parameter (α) for the cases of: a) a plate broken by a thick-skinned fault which penetrates the lithosphere, and b) a continuous plate loaded, for example, by a foreland thrust belt. Thin elastic plates and point loads are assumed (see Turcotte and Schubert, 1982).

BROKEN PLATE



UNBROKEN PLATE – FORELAND LOADING

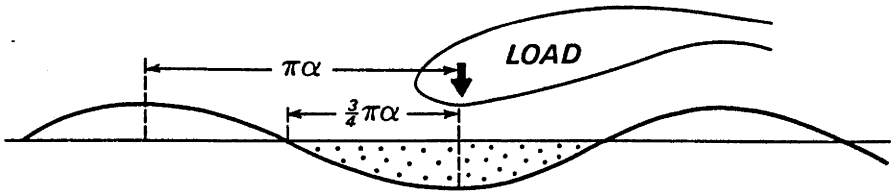
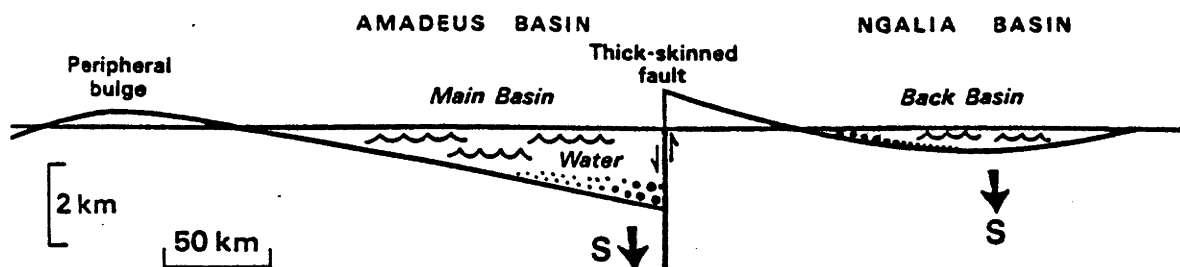


Figure 5-5. Basin formation as a result of thick-skinned faulting (see text for explanation).

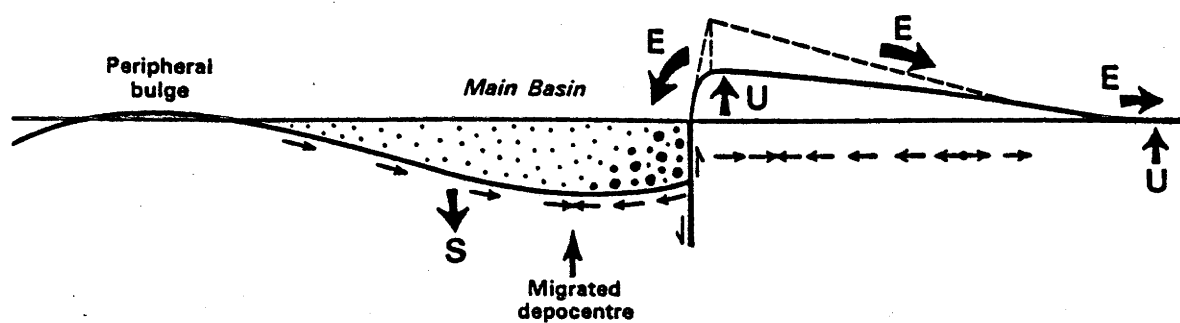
(a) Basin results from displacement on the thick-skinned fault acting on a broken plate. The model incorporates the effects of the load of the uplifted block and the load due to sea water filling the trough. (lithospheric parameters adopted in thin plate model are Effective Elasticity = $1.0 \text{E}11 \text{Nm}^{-2}$, Poisson's Ratio = 0.5, Effective Elastic Thickness of Plate = 42.8 km, Flexural Parameter = 122 km). A fault dip of 45° is assumed. The depth of the "back-basin" is exaggerated.

(b) Simultaneous erosion and deposition producing a positive feed-back effect in the above model. Accelerated erosion of the uplifted block with large topographic relief causes accelerated uplift. Similarly, the accumulating sediment load in the trough increases subsidence. It is presumed the fault alternated between locked and unlocked. The model shows deflection for the static case where the fault is locked and no compression is acting. (Lithospheric Parameters: Effective Elasticity = $0.7 \text{E}11 \text{Nm}^{-2}$; Poisson's Ratio = 0.3; Effective elastic thickness = 30 km; Flexural Parameter = 81.4 km; Flexural Rigidity = $1.72 \text{E}23 \text{Nm}$) E = Eroded mountain, U = Uplift due to buoyant effect of load being removed due to erosion, S = Subsidence due to sediment loading. Also shown are relative bending (fibre) stresses (lithospheric parameters adopted are those given in (b) above).

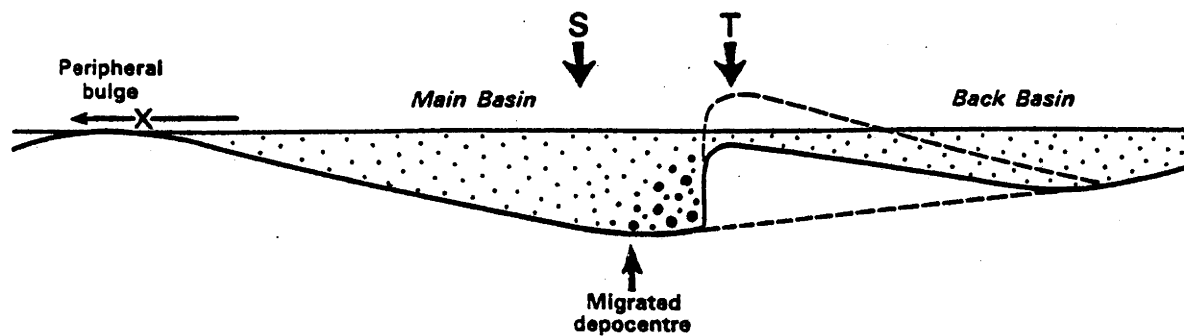
(c) Static loading by sediment (S) and mountain (T) acting on a continuous plate with no in-plane compression. When the fault is locked, the load is distributed over a continuous plate and subsidence will take place over a wider region. The basin depocentre and the peripheral bulge will migrate away from the fault. S = Sediment load, T = Topographic load.



(a) Thick-skinned faulting (broken plate)



(b) Positive feedback due to simultaneous erosion and deposition



(c) Static loading of a continuous plate

Figure: 5-6. Models for continental extension by the development of detachment shear zones (after Lister et al, 1987). For more details see discussion in text.

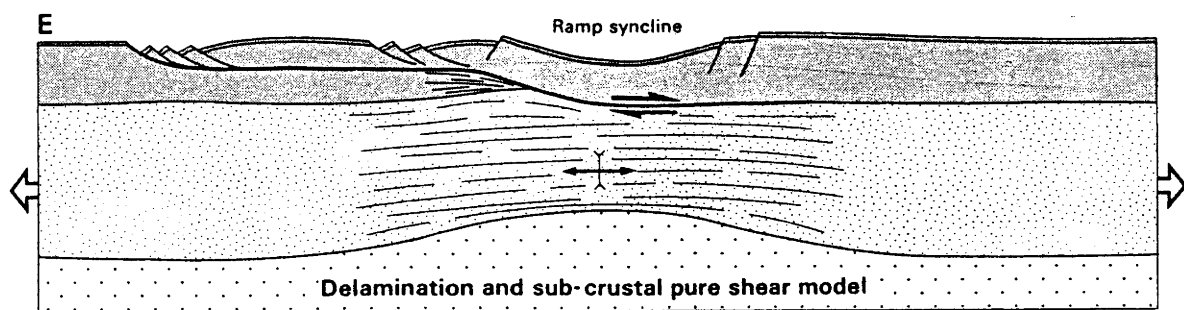
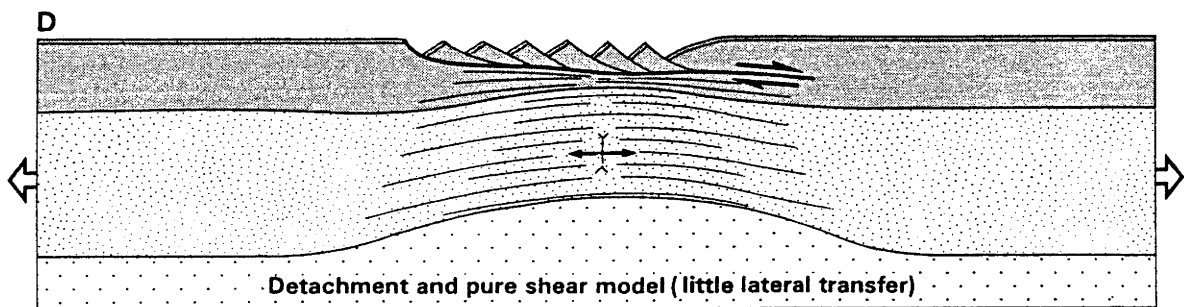
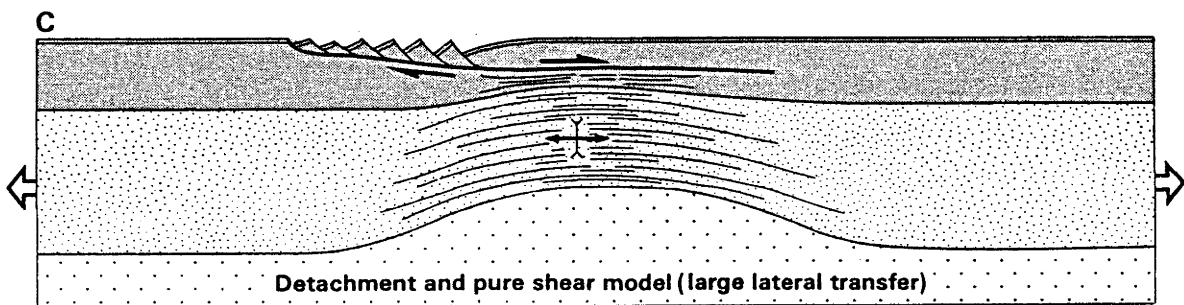
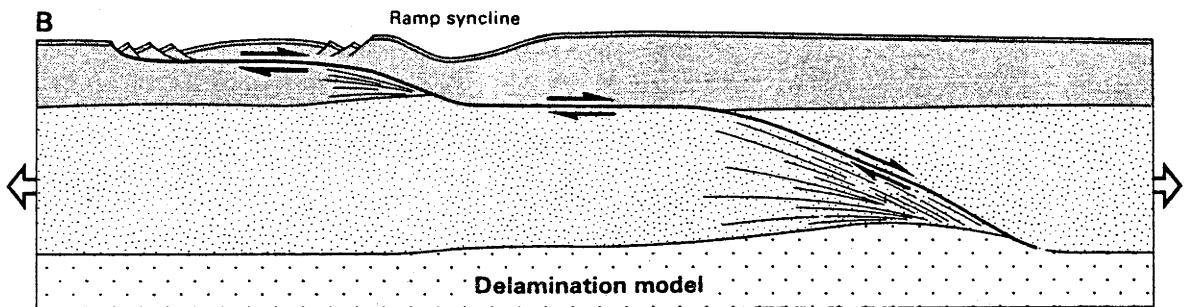
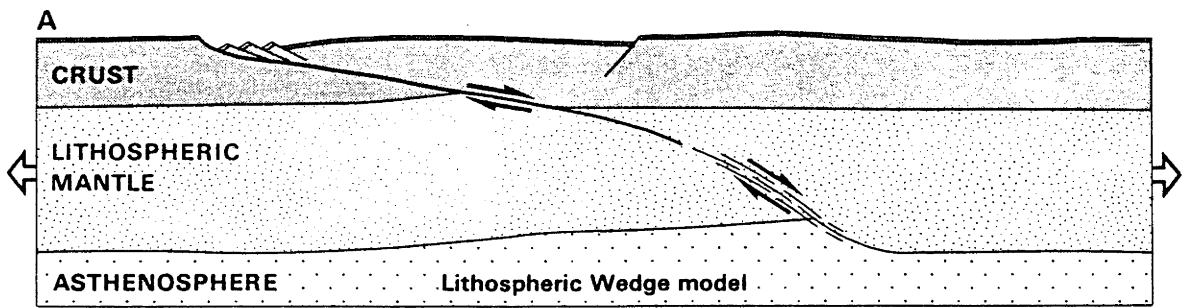


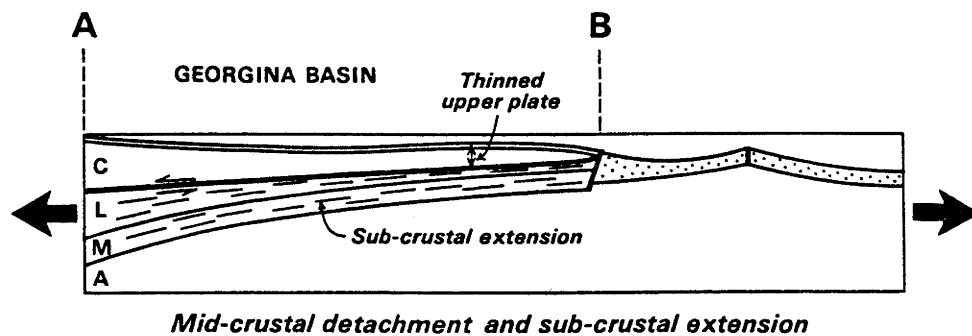
Figure: 5-7. Interpretative cross-sections across central Australia, illustrating basin formation by the flat detachment model for extension. The location of sections A-B and C-D is illustrated in Figure 5-8. C = Upper Crust (upper plate), L = Lower Crust (lower plate), M = Lithospheric Mantle (lower plate), A = Asthenosphere (the sea-floor spreading shown would develop later and is not an integral part of the model).

(a) Interpretative section A-B for continental extension for the Georgina Basin in the mid-Cambrian caused by mid-crustal delamination combined with sub-detachment pure shear of the lower crust and lithospheric mantle (lower plate). The continental plate is thinned substantially towards the upper plate margin.

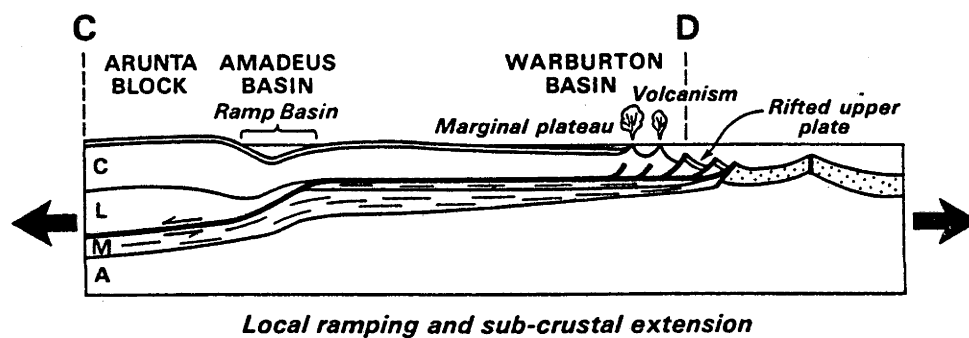
(b) Interpretative section C-D for extension in the eastern Amadeus Basin and Warburton Basins in the Early Cambrian due to local ramping on a mid-crustal detachment zone combined with sub-detachment pure shear.

(c) Interpretative section C-D for extension in the eastern Amadeus and Warburton Basins in the mid-Cambrian due to delamination and increased sub-detachment pure shear over a wider region. Subsidence is largely driven by cooling and thickening of the lithosphere (see text for further explanation).

(a) **MID-CAMBRIAN**
Depositional Interval 5



(b) **EARLY CAMBRIAN**
Depositional Interval 4



(c) **MID-CAMBRIAN**
Depositional Interval 5

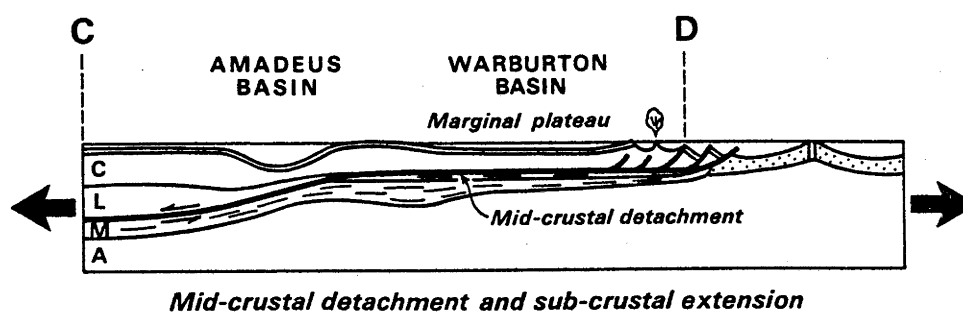
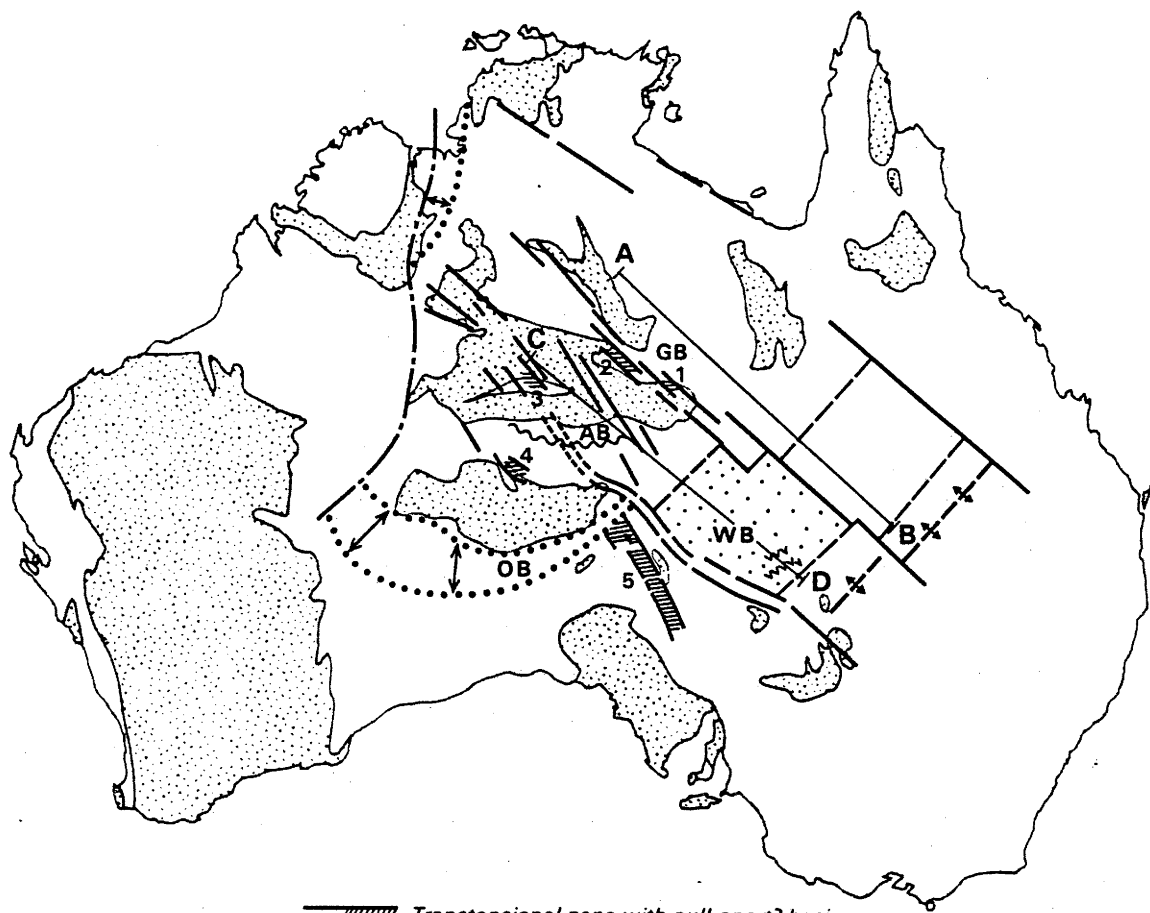
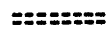
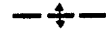
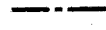
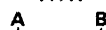
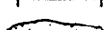
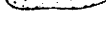


Figure: 5-8. Proposed active structures during widespread continental extension in the Early and Middle Cambrian interpreted in Figure 5-7. Section lines are A-B and C-D. A sub-horizontal detachment zone is envisaged to surface at the continental margin within the Warburton Basin (WB). Complex transtensional zones separate regions with markedly different amounts of extension. The location of the transtensional zones is inferred from discordant geological, gravity and aeromagnetic features. Pull-apart basins, inferred to have formed in the Early Cambrian, are the sub-basins for the following units: (1) Mount Baldwin Formation, (2) Central Mount Stuart Beds, (3) Yuendumu Sandstone, (4) Mount Currie Conglomerate, and (5) Sediments west of the Peake and Denison Ranges. Basins are: AB = Amadeus Basin, GB = Georgina Basin, WB = Warburton Basin, OB = Officer Basin. A zone of mild intraplate spreading is inferred along a reactivated Proterozoic mobile Belt or old geosuture (Mathur and Shaw, 1982) corresponding to the Officer Basin. Ramping on a mid-crustal detachment zone is inferred in the northern Amadeus Basin. A marginal plateau may have existed in the region of the Warburton Basin.



-  *Transtensional zone with pull-apart? basin*
-  *Discordant geological zone*
-  *Marginal plateau*
-  *Sea-floor spreading*
-  *Zone of intra-plate spreading*
-  *Sub-plate boundary*
-  *Discordant gravity lineament*
-  *Zone of ramping*
-  *Bimodal volcanism*
-  *Section line*
-  *Presently-exposed Precambrian orogenic provinces*

APPENDICES

APPENDIX 1

Mineral Abbreviations

act	actinolite	ilm	ilmenite
anh	anhydrite	ksp	alkali feldspar
an	anorthite	ky	kyanite
ant	annite (biotite)	l	liquid
al	almandine	ms	muscovite
bio	biotite	mt	magnetite
carb	carbonate	ol	olivine
cc	calcite	opx	orthopyroxene
chal	chalcopyrite	par	pargasite
chl	chlorite	phl	phlogopite
cd	cordierite	pyr	pyrope
cpx	clinopyroxene	pyor	pyrrhotite
cun	cumingtonite	pyx	pyroxene
cz	clinozoisite	qtz	quartz
di	diopside	scap	scapolite
dol	dolomite	sm	sillimanite
en	enstatite	sp	spinel
ep	epidote	sph	sphene
gnt	garnet	st	staurolite
ged	gedrite	ts	tschermak
gr	grossularite	v	vapour
hbl	hornblende	w	wollastonite
hed	hedenbergite	zir	zircon
hem	hematite	zo	zoisite
hyp	hypersthene		

APPENDIX 2 FELDSPARS

Temperature ° C	⁴⁰ Ar (10 ⁻¹⁵ mol)	³⁹ Ar (10 ⁻¹⁶ mol)	³⁶ Ar (10 ⁻¹⁷ mol)	Radiogenic ⁴⁰ Ar(%)	Cumulative ³⁹ Ar(%)	Apparent Age ±1 S.D. (Ma)
86-125 (2077): 0.0360g (TF=0.0080g); 125-180 μm; J=0.006158; microcline from granitic gneiss; K-Ar age = 628.4 Ma						
700	459	73	12	92.0	2.8	555.9±2.5
750	161	49	1	97.4	4.7	325.1±0.6
790	18511	5436	88	98.5	6.3	338.8±1.7
830	22144	6343	52	99.2	8.3	348.7±1.7
880	33793	9342	79	99.2	11.1	360.3±3.5
930	51408	13550	71	99.5	15.3	377.2±1.8
990	89496	22021	66	99.7	22.0	401.8±1.9
1040	137988	31450	156	99.6	31.6	429.9±2.0
1080	137386	27886	197	99.5	40.2	476.0±2.2
1110	117864	21056	258	99.3	46.6	531.0±2.5
1140	114264	18216	285	99.2	52.2	585.2±3.3
1170	127440	18244	243	99.4	57.7	642.0±2.8
1210	163728	18180	302	99.4	64.1	706.8±3.1
1250	234144	26744	402	99.5	72.3	774.5±3.4
1290	408960	44100	724	99.5	85.3	811.3±3.4
1350	433800	42516	667	99.5	98.8	875.8±3.6
1390	9760	1030	38	98.8	99.1	821.5±4.9
1500	25229	2804	154	98.2	100.0	783.4±3.4
1/8 TF 1550	94560	13432	377	-	-	643.2±2.9
86-126 (3003): 0.0477g (TF= 0.0070g); crush of megacryst (125-180μm); J=0.006178; microcline large megacryst in augen gneiss; K-Ar age = 511.5; 519.5 Ma						
650	22233	548	462	93.9	0.6	2183±7.9
727	7107	1242	74	96.9	2.0	531.2±2.6
810	17988	3935	62	98.9	6.2	444.4±2.1
860	14014	3502	18	99.6	10.0	397.0±1.9
900	12973	3003	15	99.6	13.3	395.6±1.8
940	10346	2610	15	99.5	16.1	400.3±1.9
995	13857	3078	16	99.6	19.5	441.0±2.0
1060	23295	3978	54	99.3	23.7	594.8±2.7
1120	62630	8406	252	98.8	32.9	676.1±2.9
1180	54903	8743	269	98.5	42.3	583.7±2.6
1230	61962	12526	279	98.6	56.0	475.3±2.2
1280	111427	25567	435	98.8	82.0	449.6±2.1
1330	72695	15603	263	98.9	98.9	451.9±2.1
1420	2629	452	29	96.7	99.4	537.7±3.1
1600	3812	549	74	94.3	100.0	612.8±3.1
1/8 TF 1600	70490	13097	610	-	-	505.9±2.3
86-131 (4178): 0.0543g (TF= 0.0064g); 120-180 μm; J=0.006086; microcline in granite gneiss						
675	50776	1006	306	98.2	0.9	2508±8.0
750	23143	2434	53	99.3	3.2	819±3.5
825	40339	6570	57	99.5	9.2	570.5±2.6
890	32651	8091	27	99.7	16.7	395.1±1.9
930	18625	4939	24	99.6	21.1	371.2±1.3
980	21964	5615	19	99.7	25.7	383.9±1.8
1030	24636	6364	26	99.6	31.6	380.2±1.8
1080	27899	7184	36	99.6	38.2	381.2±1.8
1130	35377	8786	68	99.4	46.2	395.0±1.9
1170	37000	7640	184	99.4	53.8	433.9±2.0
1200	42951	8362	101	99.3	61.5	487.3±2.3
1230	54952	9247	104	99.4	70.0	553.8±2.5
1255	62336	9160	113	99.4	78.4	622.1±2.7
1280	74174	9209	113	99.5	86.9	716.8±3.0
1310	87586	8769	132	99.5	95.0	853.6±3.5
1350	49216	4557	86	99.5	99.2	993.2±4.1
1450	11028	858	29	99.2	100.0	1035.6±4.1
1/8 TF 1550	78464	11731	405	-	-	607.8±2.7

(NOTE: insufficient ³⁷Ar detected)

Temperature ° C	⁴⁰ Ar (10 ⁻¹⁵ mol)	³⁹ Ar (10 ⁻¹⁶ mol)	³⁶ Ar (10 ⁻¹⁷ mol)	Radiogenic ⁴⁰ Ar(%)	Cumulative ³⁹ Ar(%)	Apparent Age ±1 S.D. (Ma)
<i>86-132 (RWM 865) = 0.0600g (TF=0.0152g); 150-250 μm; J=0.006149; K-feldspar in granitic gneiss</i>						
450	2497	28	332	60.7	0.02	2628±37
525	3382	53	151	86.8	0.07	2685±16
625	18174	394	192	96.9	0.4	2384±7.4
700	17940	1429	85	98.6	1.7	1021±4
750	20538	2807	72	98.9	4.1	665.1±2.9
790	12516	2948	35	99.1	5.5	415.0±2.0
830	12858	3260	36	99.1	7.9	388.5±1.9
875	14610	3920	25	99.4	10.7	370.3±1.8
910	11142	3332	16	99.5	13.1	335.3±1.8
960	14478	4015	29	99.3	16.0	359.1±1.7
1010	13614	3859	27	99.3	18.8	352.1±1.7
1060	12924	3778	22	99.4	21.5	342.6±1.6
1100	15696	4177	34	99.3	24.5	372.5±1.8
1140	20268	4452	57	99.1	27.7	441.7±2.0
1180	29946	5197	104	98.9	31.5	542.0±2.5
1220	51492	7554	188	98.9	36.9	625.6±2.8
1260	81540	11076	248	99.1	44.9	668.2±2.9
1300	124860	16782	343	99.2	57.0	674.7±2.9
1325	117360	17094	294	99.2	69.4	631.1±2.8
1350	58002	8772	160	99.1	75.7	610.8±2.7
1370	13650	2079	52	98.8	77.2	605.7±2.7
1440	28692	4261	99	98.9	80.3	619.4±2.8
1600	18810	2564	379	94.0	82.1	637.6±2.8
‡ TF 1600	22967	3479	117	—	—	606.7±5.8

86-133 (2087): 0.0571g (TF=0.0066g); 100-200 μm; J=0.006179; microcline in granitic gneiss

700	10289	3055	412	88.1	2.6	303.6±1.5
750	7931	2635	30	98.8	4.9	304.2±1.5
800	11831	3801	26	99.3	8.1	315.1±1.5
875	22712	7080	27	99.6	14.1	317.9±1.6
975	30137	9404	23	99.7	22.1	325.0±1.6
1040	27642	8080	33	99.6	29.1	344.6±1.7
1105	43487	11763	80	99.4	39.1	369.0±1.8
1145	47844	12516	132	99.1	50.0	379.7±1.8
1170	41957	10689	112	99.1	58.9	388.7±1.8
1200	43230	10638	124	99.1	68.0	400.8±1.9
1225	41540	9781	114	99.1	76.3	417.1±2.0
1260	47718	10929	181	98.8	85.7	426.3±2.0
1300	52977	11837	184	98.9	95.7	436.2±2.1
1350	21058	4414	76	98.9	99.5	461.4±2.1
1500	3385	634	45	96.0	100.0	496.2±2.6
‡ TF 1500	51817	12989	412	—	—	388.8±1.9

86-134 (2065): 0.0460g (TF=0.0078g); 125-180 μm; J=0.006216; Orthoclase in garnet-sillimanite-biotite-plagioclase quartz gneiss

650	13510	800	297	93.5	0.9	1233.7±4.7
700	4678	1063	24	98.4	2.0	430.0±2.2
750	9333	2517	20	99.3	4.8	371.8±1.8
800	16206	4531	19	99.6	9.8	360.8±1.7
850	18777	5442	16	99.7	15.7	349.3±1.6
900	21280	6150	23	99.6	22.5	350.2±1.7
950	21592	6302	17	99.7	29.4	347.4±1.7
1005	24311	7116	19	99.7	37.1	346.3±1.7
1060	24564	6992	13	99.8	44.8	355.9±1.7
1105	16417	4513	22	99.5	49.8	366.1±1.7
1150	lost through leak valve					
1200	lost through leak valve					
1240	52118	13147	116	99.3	77.1	395.0±1.9
1265	50692	12673	113	99.2	91.0	398.0±1.9
1290	28423	6914	72	99.2	98.3	407.4±1.9
1340	5561	1270	42	97.7	99.7	425.6±2.1
1500	2124	323	111	84.3	100.0	534.4±4.3
‡ TF 1500	57502	14219	892	—	—	387.5±1.9

(NOTE: insufficient ³⁷Ar detected)

MUSCOVITES

Temperature ° C	⁴⁰ Ar (10 ⁻¹⁵ mol)	³⁹ Ar (10 ⁻¹⁶ mol)	³⁷ Ar (10 ⁻¹⁶ mol)	³⁶ Ar (10 ⁻¹⁶ mol)	Radiogenic ⁴⁰ Ar(%)	Cumulative ³⁹ Ar(%)	Apparent Age ±1 S.D. (Ma)
86-123(2079):0.0314g (TF=0.0148g); 150-250 μm; J=0.008813 ;muscovite in granite gneiss ; K-Ar age = 1124.9Ma							
625	1800	215	19	172	71.8	0.4	765.7±6.2
700	2917	307	31	26	97.4	0.9	1075.9±5.1
740	3426	349	14	12	98.9	1.6	1114.3±5.5
770	4198	428	9	12	99.1	2.4	1116.8±4.5
810	6933	707	-	17	99.2	3.6	1116.8±4.9
850	11367	1155	14	27	99.3	5.7	1120.4±4.3
880	27466	2788	15	54	99.4	10.7	1122.1±4.3
910	41197	4170	2	50	99.6	18.2	1126.4±5.2
920	33912	3429	21	30	99.7	24.3	1128.3±4.5
935	38465	3900	1	27	99.8	31.3	1126.6±4.4
945	32373	3284	30	15	99.8	37.2	1125.7±4.4
960	37021	3762	-	40	99.7	43.9	1124.0±4.4
980	29821	3040	-	22	99.8	49.4	1121.5±4.4
1010	34414	3507	-	22	99.8	55.6	1122.5±4.4
1050	49957	5068	20	40	99.7	64.7	1125.5±4.4
1400	97246	9831	126	36	99.9	100.0	1129.3±4.4
¹ / ₈ TF 1450	169312	17168	416	22	-	-	917.2±3.8
86-124 (RWM): 0.0546g (T.F. =0.0057g); 150-425μm; J=0.008813; muscovite in granite gneiss; K-Ar age = 1074.7Ma							
625	3149	435	14	454	58.7	0.5	573.5±3.7
700	5305	627	11	91	94.8	1.2	939.7±4.4
760	10816	1232	26	74	97.9	2.5	1017.3±4.1
810	17002	1930	19	4	99.2	4.5	1030.0±4.1
860	31750	3570	-	73	99.3	8.4	1038.3±4.2
890	50723	5607	3	98	99.4	14.3	1052.5±4.2
910	44685	4887	21	67	99.5	19.6	1062.3±4.3
925	50379	5437	41	63	99.6	25.3	1073.7±4.3
945	50805	5432	17	19	99.9	31.1	1083.3±4.2
965	73928	7873	14	34	99.8	39.5	1086.2±4.3
995	80664	6545	14	51	99.8	48.6	1089.7±4.3
1015	67049	7098	39	44	99.8	56.2	1090.0±4.2
1045	92110	9631	21	45	99.8	66.5	1101.1±4.3
1075	99263	10265	45	36	99.9	77.4	1110.7±4.4
1105	109255	11340	100	45	99.9	89.6	1107.7±4.3
1145	85613	8845	26	2	100.0	99.0	1112.4±4.3
1220	9511	955	25	11	99.6	100.0	1133.2±4.4
¹ / ₈ TF 1450	91029	9610	166	33	-	-	1085.9±4.3

HORNBLENDES

Temperature ° C	⁴⁰ Ar (10 ⁻¹⁵ mol)	³⁹ Ar (10 ⁻¹⁶ mol)	³⁷ Ar (10 ⁻¹⁶ mol)	³⁶ Ar (10 ⁻¹⁷ mol)	Radiogenic ⁴⁰ Ar(%)	Cumulative ³⁹ Ar(%)	Apparent Age ±1 S.D. (Ma)
<i>86-122 (2066): 0.1799g (TF=0.0155g); 200-300 μm; J=0.008847; hornblende in granulite; K-Ar age = 1426.9 Ma</i>							
700	2281	19	502	420	45.8	0.3	3219±148
800	439	12	452	5	66.4	0.5	2158±68
900	600	18	1172	76	64.2	0.8	1999±52
980	605	21	1591	37	84.1	1.1	2118±41
1070	1393	76	3526	51	91.5	2.4	1678±13
1120	34109	2493	82952	538	97.5	44.9	1429.8±7.3
1130	7232	533	17718	119	97.3	53.9	1420.3±8.7
1130(2)	1866	142	4528	46	94.9	56.3	1363.5±10.3
1145	3679	272	8882	59	97.4	60.9	1416.6±8.2
1165	2956	226	7300	54	96.8	64.8	1376.6±7.8
1200	9180	713	22883	148	97.5	76.9	1370.4±8.3
1240	15525	1172	38714	211	98.2	96.8	1405.2±8.3
1270	817	58	2065	31	90.9	97.8	1384.9±16.5
1300	936	63	2941	27	94.3	98.9	1491.4±12.4
1400	997	67	3740	53	87.6	100.0	1430.8±14.7
1/3 TF 1450	9001	576	18213	616	-	-	1384.0±7.5
<i>86-135 (2080): 0.3284g (TF=0.0183g); 100-200 μm; J=0.009015; hornblende in amphibolite; K-Ar age = 1138±7.1 Ma</i>							
750	14371	1738	3101	1130	76.9	2.0	818.5±3.8
800	2003	337	479	100	85.3	2.3	679.3±4.3
850	2108	325	665	63	91.4	2.7	774.1±10.5
940	4883	816	3428	118	93.4	3.6	738.6±3.6
1030	117173	11678	43053	363	99.4	16.8	1159±4.4
1055	73890	7139	22998	133	99.7	24.9	1188.4±4.6
1070	85647	8148	25595	162	99.7	34.1	1201.6±4.7
1085	109357	10719	33365	200	99.7	46.1	1175.9±4.6
1095	83381	8240	25497	132	99.8	53.4	1169.5±4.5
1105	73168	7323	22765	110	99.8	63.8	1158.4±4.5
1115	62002	6286	19477	110	99.7	70.8	1147±4.4
1135	82002	8364	26216	99	99.9	80.3	1143.4±4.4
1160	80720	8256	26571	150	99.7	89.6	1139.8±4.4
1200	67421	6814	23392	122	99.8	97.3	1150.2±4.5
1300	22748	2266	8174	55	99.6	99.8	1161.2±4.6
1450	1178	108	1091	51	88.1	100.0	1130±9.5
1/3 TF 1450	52448	5144	17074	518	-	-	1155.0±4.5
<i>86-136 (2090): 0.3790g (TF=0.0150g); 125-180μm; J=0.008916; hornblende in amphibolite</i>							
750	7210	608	1822	721	98.7	0.9	1006.0±4.7
900	7436	957	2066	91	96.6	2.3	925.0±3.9
975	5518	638	3900	69	96.9	3.2	1009.4±4.6
1020	9699	938	7235	72	98.4	4.5	1169.3±4.8
1060	55069	5109	28868	198	99.4	11.9	1213.3±4.6
1075	69850	6420	34019	170	99.7	21.2	1223.7±4.6
1090	96228	8903	46428	278	99.6	34.1	1216.8±4.6
1100	71631	6689	34576	213	99.5	43.8	1208.2±4.6
1110	77809	7364	37976	209	99.6	54.4	1197.3±4.6
1120	47944	4586	23525	102	99.8	61.0	1186.8±4.6
1135	38696	3745	19314	98	99.7	66.5	1178.4±4.6
1155	38355	3733	19329	88	99.8	71.9	1174.4±4.6
1185	62687	6041	34468	168	99.6	80.3	1181.5±4.5
1220	86450	8281	42675	188	99.8	92.6	1188.0±4.5
1400	54008	5401	26352	164	99.5	100.0	1192.0±4.5
1/3 TF 1450	29220	2748	14399	261	-	-	1186.6±8.1

APPENDIX 3: Probe analyses used in PT calculations (Method of analysis after Ware, 1981)

SITE 1:									
H601/1	ILM	BIOT 1	HBE 1						
SiO2	0.00	0.000	36.35	5.553	40.96	6.304			
TiO2	50.13	1.917	5.63	0.647	1.61	0.187			
Al2O3	0.00	0.000	13.71	2.469	12.07	2.190			
FeO	49.64	2.111	16.81	2.148	16.22	2.087			
MnO	0.34	0.015	0.00	0.000	0.00	0.000			
MgO	0.48	0.036	12.49	2.844	10.40	2.385			
CaO	0.09	0.005	0.00	0.000	11.52	1.900			
K2O			9.27	1.806	1.90	0.373			
Na2O			0.00	0.000	1.18	0.351			
Cl			0.14	0.036	0.23	0.059			
TOTAL			94.41	15.504	96.10	15.836			
				-22.0		-23.0			

SITE 2:									
H601/2	OPX 4	CPX 5	PLAG 5R	BIOT 2	HBE 2				
SiO2	50.70	1.958	50.18	1.947	53.86	2.445	35.74	5.566	41.55
TiO2	0.00	0.000	0.00	0.000	0.00	0.000	5.15	0.603	1.83
Al2O3	1.27	0.058	2.50	0.114	28.94	1.549	13.61	2.498	13.29
FeO	27.71	0.895	10.10	0.328	0.00	0.000	15.43	2.010	16.23
MnO	0.54	0.018	0.00	0.000	0.00	0.000	0.00	0.000	0.000
MgO	18.53	1.067	12.03	0.696	0.14	0.010	12.85	2.983	10.21
CaO	0.46	0.019	21.77	0.905	11.26	0.548	0.15	0.024	11.92
K2O	0.00	0.000	0.00	0.000	0.27	0.016	9.04	1.796	2.18
Na2O	0.00	0.000	0.19	0.014	5.03	0.442	0.00	0.000	1.15
Cl	0.00	0.000	0.00	0.000	0.05	0.004	0.14	0.038	0.29
TOTAL	99.20	4.013	96.77	4.003	99.55	5.013	92.12	15.518	98.64
		-6.0		-6.0		-8.0		-22.0	-23.0

SITE 2:									
H602/1	ILM	GA 3	BI 3	OPX 1	PLAG 2	GA 3	HBE 1		
SiO2	0.00	0.000	37.71	2.993	35.85	5.556	50.81	1.950	58.28
TiO2	47.06	1.222	0.00	0.000	5.50	0.641	0.00	0.000	0.00
Al2O3	0.20	0.008	20.95	1.960	13.60	2.483	1.35	0.061	27.94
FeO	52.76	1.524	31.60	2.097	19.79	2.565	31.50	1.011	0.00
MnO	0.00	0.000	1.06	0.071	0.00	0.000	0.49	0.016	0.00
MgO	0.38	0.020	3.76	0.445	10.38	2.398	16.74	0.958	0.13
CaO	0.00	0.000	5.41	0.460	0.00	0.000	0.57	0.023	9.17
K2O	0.00	0.000	0.00	0.000	9.27	1.833	0.00	0.000	0.19
Na2O	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	6.55
Cl	0.00	0.000	0.00	0.000	0.55	0.143	0.00	0.000	0.00
TOTAL	100.39	2.774	100.49	8.027	94.94	15.621	101.46	4.019	102.25
		-4.0		-12.0		-22.0		-6.0	-8.0

SITE 2:									
H602/1	ILM	GA 3	BI 3	OPX 1	PLAG 2	GA 3	HBE 1		
SiO2	0.00	0.000	37.71	2.993	35.84	2.556	37.84	2.976	40.41
TiO2	47.06	1.222	0.00	0.000	0.00	0.000	0.00	0.000	1.47
Al2O3	0.20	0.008	20.95	1.953	21.07	1.444	19.53	12.51	2.272
FeO	52.76	1.524	31.60	2.097	30.09	0.000	1.979	19.00	2.448
MnO	0.00	0.000	1.06	0.071	1.30	0.086	0.00	0.000	0.000
MgO	0.38	0.020	3.76	0.445	4.07	0.447	8.85	2.031	8.85
CaO	0.00	0.000	5.41	0.460	5.80	0.573	11.43	1.887	11.43
K2O	0.00	0.000	0.00	0.000	0.08	0.008	2.32	0.457	2.32
Na2O	0.00	0.000	0.00	0.000	0.00	0.000	1.38	0.412	1.38
Cl	0.00	0.000	0.00	0.000	0.05	0.007	0.65	0.169	0.65
TOTAL	100.39	2.774	100.49	8.059	98.03	15.838	98.03	16.071	98.03
		-4.0		-12.0		-22.0		-23.0	-23.0

P.2

SITE 2:												
H602/2												
	GNT 1	OPX 2	PLAG 2	GNT 2R	OPX 2B	OPX 2B	OPX 2B	OPX 2B	OPX 2B	OPX 2B	OPX 2B	OPX 2B
S102	37.48	2.998	50.20	1.953	57.31	2.569	37.65	2.990	51.11	1.964	50.31	1.972
Al ₂ O ₃	20.80	1.962	1.42	0.065	27.27	1.441	20.96	1.962	0.99	0.045	0.91	0.042
Fe ₂ O ₃	0.00	0.000	0.56	0.016	0.00	0.000	0.00	0.000	0.36	0.010	0.46	0.014
FeO	29.13	1.949	29.56	0.962	0.00	0.000	30.17	2.004	28.96	0.931	29.05	0.952
MnO	1.07	0.073	0.26	0.009	0.00	0.000	1.27	0.085	0.30	0.010	0.23	0.008
MgO	4.14	0.493	16.88	0.979	0.00	0.000	3.68	0.436	17.71	1.015	17.15	1.002
CaO	6.33	0.543	0.30	0.013	8.70	0.418	6.33	0.539	0.36	0.015	0.25	0.010
K ₂ O	0.06	0.006	0.00	0.000	0.25	0.014	0.00	0.000	0.00	0.000	0.00	0.000
Na ₂ O	0.00	0.000	0.00	0.000	6.34	0.551	0.14	0.022	0.00	0.000	0.00	0.000
SO ₃	0.00	0.000	0.10	0.003	-0.00	0.000	0.00	0.000	0.22	0.006	0.00	0.000
Cl					0.00	0.000	0.00	0.000	0.07	0.004	0.00	0.000
TOTAL	99.01	8.024	99.29	4.000	99.88	4.993	100.21	8.039	100.08	4.000	98.35	4.000
	-12.0	-6.0			-8.0		-12.0		-6.0			-6.0

SITE 3:		
H618A/1	CPX 2R	OPX 1
SiO2	51.06	1.930
Al2O3	2.08	0.093
Fe2O3	2.32	0.066
FeO	9.97	0.315
MnO	0.13	0.004
MgO	11.87	0.669
CaO	22.30	0.903
K2O	0.00	0.000
Na2O	0.26	0.019
TiO2		0.00
TOTAL	100.00	4.000
		100.00
		0.000
		4.000
		-6.0

APPENDIX 3: (Cont.) P.3

SITE 3:									
H618A/2	PL3R		CPX 3		HBE 1		ILM 1		
SiO ₂	52.43	2.388	51.53	1.949	41.28	6.268	0.00	0.000	
TiO ₂			0.00	0.000	1.80	0.206	49.37	1.910	
Al ₂ O ₃	30.37	1.623	1.92	0.086	12.83	2.295	0.00	0.000	
Fe ₂ O ₃	0.00	0.000	0.55	0.016	0.00	0.000	0.00	0.000	
FeO	0.00	0.000	11.61	0.367	18.32	2.326	49.29	2.121	
MnO	0.00	0.000	0.00	0.000	0.00	0.000	0.43	0.019	
MgO	0.00	0.000	11.86	0.669	8.92	2.019	0.52	0.040	
CaO	12.73	0.618	22.53	0.913	11.77	1.914	0.00	0.000	
K ₂ O	0.18	0.011	0.00	0.000	1.85	0.358			
Na ₂ O	4.28	0.376	0.00	0.000	1.17	0.345			
Cl			0.00	0.000	0.06	0.016			
TOTAL	100.00	5.005	100.00	4.000	98.00	15.746	99.61	4.090	
		-8.0		-6.0		23.0		-6.0	

SITE 4:									
H619/1	BI 2R		GA 5						
SiO ₂	37.16	5.471	37.73	2.972					
TiO ₂	4.49	0.497	0.00	0.000					
Al ₂ O ₃	16.59	2.879	21.42	1.989					
Cr ₂ O ₃	0.00	0.000	0.00	0.000					
FeO	13.22	1.628	32.18	2.120					
MnO	0.00	0.000	0.69	0.046					
MgO	14.45	3.172	7.03	0.825					
CaO	0.00	0.000	0.96	0.081					
K ₂ O	10.08	1.894	0.00	0.000					
Na ₂ O	0.00	0.000	0.00	0.000					
Cl	0.00	0.000	0.00	0.000					
TOTAL	96.00	15.540	100.00	8.033					
		22.0		-12.0					

APPENDIX 3: (Cont.) P.4

SITE 4:													
H619/2		GA 1		BI IR		PL 1		TIM 1		RUT IR		KSP IR	
SiO2	37.95	2.979	16.14	2.295	34.41	1.570	0.18	0.009	0.29	0.008	40.14	1.874	37.76
TiO2	0.00	0.000	1.79	0.191	0.00	0.000	52.16	1.972	97.64	1.987	0.00	0.000	0.000
Al2O3	21.38	1.978	58.63	9.823	55.90	3.007	0.12	0.007	0.11	0.004	46.54	2.561	21.54
Fe2O3	1.09	0.064	0.00	0.000	0.00	0.000							1.997
FeO	31.04	2.037	5.32	0.633	0.00	0.000	46.67	1.962	0.24	0.005	0.00	0.000	32.07
MnO	0.55	0.036	0.00	0.000	0.00	0.000	0.18	0.007	0.00	0.000	9.00	0.000	0.57
MgO	7.06	0.826	5.96	1.264	0.23	0.016	0.76	0.057	0.00	0.000	0.00	0.000	7.11
CaO	0.94	0.079	0.08	0.012	2.35	0.115			0.00	0.000	8.72	0.520	0.96
K2O	0.00	0.000	4.26	0.772	0.11	0.006	0.00	0.000	0.00	0.000	0.00	0.000	0.000
Na2O	0.00	0.000	0.00	0.000	4.85	0.430	0.00	0.000	0.00	0.000	3.34	0.302	0.00
Cl	0.00	0.000	0.05	0.012	0.00	0.000							
TOTAL	100.00	8.000	92.23	15.001	97.85	5.144	100.03	4.015	98.28	2.004	98.73	5.256	100.00
				22.0		-8.0	-6.0		-4.0		-8.0		-12.0

SITE 5:						
G8B1/1	KSP		GNT		BIOT	
P2O5	0.00	0.000	0.10	0.007	0.00	0.000
SiO2	63.67	2.983	36.94	2.975	35.11	5.395
TiO2			0.00	0.000	3.62	0.419
Al2O3	18.68	1.032	21.20	2.012	18.25	3.305
FeO			35.25	2.374	17.21	2.211
MnO			1.02	0.070	0.00	0.000
MgO			3.74	0.449	9.85	2.256
CaO	0.00	0.000	1.19	0.102	0.00	0.000
K2O	14.42	0.862	0.07	0.007	9.68	1.897
Na2O	1.21	0.110	0.22	0.035	0.00f	0.000
SO3	0.00	0.000				
TOTAL	97.98	4.987	99.72	8.030	93.73	15.482
		-8.0		-12.0		22.0

APPENDIX 3: (Cont.) P.5

SITE 5:									
G8B/2	KSP	PLAG	KS	PLAG	GA	PLAG	GA	PLAG	GA
P ₂ O ₅	0.00	0.000	0.00	0.006	0.00	0.000	0.00	0.000	0.000
SiO ₂	63.98	2.989	58.56	2.591	63.04	3.000	37.13	3.014	34.77
Al ₂ O ₃	18.66	1.027	26.80	1.398	18.05	1.012	20.75	1.986	17.71
CaO	0.00	0.000	8.05	0.381	0.00	0.000	1.31	0.114	0.00
K ₂ O	13.44	0.801	0.17	0.010	13.26	0.805	0.06	0.006	9.17
Na ₂ O	1.79	0.162	7.12	0.610	1.74	0.160	0.00	0.000	0.00
SO ₃	0.00	0.000	0.15	0.005	0.00	0.000	0.00	0.000	0.000
TiO ₂							0.00	0.000	2.84
FeO							0.00	0.000	0.335
MnO							0.00	0.000	34.27
MgO							0.00	0.000	2.327
TOTAL	97.86	4.979	101.02	5.001	96.08	4.977	98.46	7.996	15.500
	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0	22.0

SITE 6:									
G8C/1	PLAG 1C	PLAG 1D	GNT	GA 1B	PLAG 1C	PLAG 1D	GNT	GA 1B	PLAG 1C
P ₂ O ₅	0.13	0.005	0.00	0.000	0.00	0.000	0.00	0.000	0.000
SiO ₂	59.75	2.609	56.97	2.614	37.76	2.992	37.69	2.969	34.79
Al ₂ O ₃	27.17	1.398	25.70	1.390	21.57	2.015	21.78	2.022	2.292
FeO	0.00	0.000	0.00	0.000	34.34	2.276	34.79	2.292	0.000
MnO	0.00	0.000	0.00	0.000	0.76	0.051	0.87	0.038	0.000
MgO	0.00	0.000	0.00	0.000	4.56	0.538	4.53	0.532	0.000
CaO	7.68	0.359	7.39	0.363	1.29	0.110	1.29	0.109	0.000
K ₂ O	0.26	0.015	0.20	0.011	0.00	0.000	0.00	0.000	0.000
Na ₂ O	7.27	0.615	6.92	0.616	0.25	0.039	0.21	0.032	0.000
SO ₃	0.00	0.000	0.10	0.004	0.00	0.000	0.12	0.007	0.000
Cl	0.00	0.000	0.00	0.000	0.00	0.000	0.06	0.009	0.000
TOTAL	102.26	5.000	97.27	4.998	100.52	8.020	101.36	8.030	-12.0
	-8.0	-8.0	-8.0	-8.0	-12.0	-12.0	-12.0	-12.0	-12.0

APPENDIX 3: (Cont.) p.6

SITE 6:
G8C/2

	BIOT	GNT
P2O5	0.00	0.000
SiO2	33.85	37.81
TiO2	3.44	0.00
Al2O3	17.22	21.24
Cr2O3	1.51	0.190
FeO	16.52	34.27
MgO	9.20	4.11
CaO	0.00	1.66
K2O	8.85	0.00
Na2O	0.00	0.16
Cl	0.05	0.014
MnO		0.87
TOTAL	90.64	100.28
		-12.0

SITE 7:
N11A/1

	GNT 1A	BIOT 1A	GNT 1B	BIOT 1B
SiO2	75.46	33.97	37.38	34.69
TiO2	0.00	3.63	0.00	3.79
Al2O3	7.81	14.70	20.35	15.20
FeO	11.51	21.60	27.55	22.81
MnO	1.64	0.00	4.86	0.00
MgO	0.82	8.63	2.49	8.16
CaO	3.35	0.00	7.03	0.00
K2O	0.26	9.20	0.00	9.19
SO3	0.00	0.13	0.00	0.00
Cl	0.00	0.48	0.00	0.51
TOTAL	100.85	92.34	99.66	94.34
		-12.0	-12.0	22.0

SITE 7:

SITE 7:		GNT 3A		BIOT 3A		GNT 3B		BIOT 3C		MT 3A		GNT 3C		BIOT 3C		HBE 3A	
SITE 7:		GNT 3A		BIOT 3A		GNT 3B		BIOT 3C		MT 3A		GNT 3C		BIOT 3C		HBE 3A	
SS102	37.25	3.017	34.94	5.540	46.43	3.574	40.43	6.121	1.01	0.052	53.53	3.809	34.41	5.513	37.70	6.073	
TT102	0.00	0.000	4.12	0.491	0.00	0.080	3.73	0.424	0.15	0.006	0.00	0.000	4.17	0.503	1.03	0.124	
Al ₂ O ₃	20.32	1.939	15.26	2.853	17.33	1.572	14.80	2.640	0.67	0.041	25.78	2.162	15.43	2.914	13.85	2.628	
FeO	27.59	1.869	21.22	2.814	23.69	1.525	19.40	2.456	87.52	3.793	0.32	0.019	20.26	2.715	22.67	3.054	
MnO	3.96	0.272	0.00	0.000	3.82	0.249	0.00	0.000									
MgO	2.00	0.242	8.11	1.916	1.64	0.188	7.48	1.688	0.20	0.016	0.16	0.017	7.97	1.903	5.38	1.293	
CaO	7.60	0.660	0.00	0.000	6.42	0.530	0.00	0.000	0.00	0.000	8.26	0.630	0.00	0.000	10.98	1.894	
K ₂ O	0.00	0.000	9.17	1.856	0.06	0.006	8.34	1.610	0.15	0.010	0.13	0.028	8.96	1.832	2.30	0.472	
Na ₂ O	0.20	0.031	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	5.79	0.799	0.00	0.000	1.20	0.373	
Cl	0.00	0.000	0.42	0.112	0.00	0.000	0.42	0.109	0.00	0.000	0.12	0.014	0.14	0.110	0.96	0.263	
P ₂ O ₅									0.00	0.000	0.14	0.009	0.00	0.000	0.00	0.000	
V ₂ O ₃									0.14	0.006	0.00	0.000	0.00	0.000	0.00	0.000	
SO ₃									0.00	0.000	0.24	0.013	0.17	0.020	0.00	0.000	
TOTAL	98.92	8.029	93.24	15.582	99.39	7.643	94.60	15.048	89.84	3.923	94.63	7.498	91.78	15.512	96.00	16.174	
	-12.0		22.0		-12.0		22.0		-4.0		-12.0		22.0		23.0		

SITE 7:

FILE 7:	NIIL/3	GNT 4A	HBE 4A	HBE 4B	MT 4A	BIOT 4A	BIOT 4B	PLAG 4B	BIOT 4C	PLAG 4A		
P205	0.11	0.008	0.24	0.033	0.00	0.000	0.00	0.000	34.92	5.550	56.65	2.586
S102	36.90	3.014	37.66	6.143	0.61	0.032	34.13	5.553	34.92	5.550	56.65	2.586
T102	0.00	0.000	1.11	0.137	0.00	0.000	4.36	0.533	3.48	0.416	0.00	0.000
Al2O3	20.18	1.943	13.43	2.581	13.69	2.618	14.88	2.853	14.82	2.776	26.48	1.425
V2O3	0.00	0.000	0.60	0.000	0.27	0.011						
FeO	26.21	1.791	21.60	2.946	87.53	3.849	20.02	2.724	22.32	2.966	0.00	0.000
MnO	4.87	0.337	0.00	0.000	0.00	0.000					0.00	0.000
MgO	2.41	0.293	5.33	1.297	0.00	0.000	7.84	1.901	8.47	2.005	0.00	0.000
CaO	7.05	0.617	10.66	1.863	0.00	0.000	0.11	0.019	0.00	0.000	8.33	0.407
K2O	0.00	0.000	2.23	0.464	0.00	0.000	8.73	1.811	9.18	1.860	0.31	0.018
Na2O	0.00	0.000	0.94	0.297	0.00	0.000	0.00	0.000	0.00	0.000		
SiO3	0.00	0.000	0.00	0.000	0.19	0.007	0.00	0.000	0.00	0.000		
Cl	0.00	0.000	0.84	0.232	0.00	0.000	0.34	0.093	0.36	0.098	0.00	0.000
TOTAL	97.73	8.002	94.03	15.992	89.11	3.931	90.41	15.487	93.56	15.673	97.97	4.985
	-12.0		23.0	23.0	-4.0		22.0	-8.0			-8.0	-8.0

APPENDIX 3: (Cont.) P.8

SITE 8:														
D4/1	GNT 1B	GNT 1D	PLAG 2BR	PLAG 1C	OPX 1B	OPX 1C	OPX 1D	HBE 1A						
SiO ₂	38.87	3.066	37.96	3.000	57.50	2.588	58.17	2.600	51.29	1.971	50.38	1.962	42.49	6.382
Al ₂ O ₃	21.29	1.979	21.39	1.993	26.77	1.420	26.71	1.407	1.37	0.062	1.34	0.062	12.75	2.256
Fe ₂ O ₃	0.00	0.000	0.13	0.008	0.00	0.000	0.00	0.000	0.00	0.000	0.52	0.015	0.81	0.000
FeO	26.51	1.749	25.85	1.709	0.00	0.000	0.00	0.000	28.06	0.901	27.78	0.905	16.66	2.092
MnO	4.30	0.287	4.16	0.279	0.00	0.000	0.00	0.000	1.30	0.042	1.34	0.044	0.16	0.021
MgO	3.06	0.360	3.73	0.439	0.00	0.000	0.00	0.000	17.50	1.002	17.09	0.992	9.53	2.134
CaO	5.97	0.504	6.77	0.573	8.38	0.404	8.10	0.388	0.49	0.020	0.51	0.021	11.10	1.786
K ₂ O	0.00	0.000	0.00	0.000	0.15	0.008	0.24	0.014	0.00	0.000	0.00	0.000	1.77	0.340
Na ₂ O	0.00	0.000	0.00	0.000	6.56	0.572	6.79	0.588	0.00	0.000	0.00	0.000	1.37	0.400
TiO ₂									0.00	0.000	0.00	0.000	1.99	0.224
Cl									0.00	0.000	0.00	0.000	0.17	0.042
TOTAL	100.00	7.945	100.00	8.000	99.36	4.992	100.00	4.997	100.00	3.999	98.97	4.000	98.00	15.678
		-12.0		-12.0		-8.0		-8.0		-6.0		-6.0		23.0

SITE 8:												
D4/2	GNT 1C	ILM D4	BIOT 2	GNT 1A								
SiO ₂	38.03	2.998	36.11	5.499	37.85	2.991						
TiO ₂	0.00	0.000	51.14	1.937	5.09	0.583	0.00	0.000				
Al ₂ O ₃	20.78	1.930	0.29	0.017	14.71	2.640	20.76	1.933				
Fe ₂ O ₃	1.75	0.104	0.00	0.000	0.00	0.000	1.53	0.091				
FeO	24.90	1.641	46.40	1.955	17.51	2.230	25.40	1.679				
MnO	3.19	0.213	1.02	0.043	0.00	0.000	3.23	0.216				
MgO	4.31	0.506	0.24	0.018	12.00	2.723	4.18	0.493				
CaO	6.86	0.579	0.08	0.004	0.00	0.000	6.99	0.592				
K ₂ O	0.00	0.000	0.06	0.004	9.53	1.852	0.06	0.006				
Na ₂ O	0.19	0.029	0.00	0.000	0.00	0.000	0.00	0.000				
Cl			0.06	0.015	0.00	0.000	0.00	0.000				
TOTAL	100.00	8.000	100.00	4.018	95.00	15.540	100.00	8.000				
		-12.0		-6.0		22.0		-12.0				

APPENDIX 3: (Cont.) P.9

SITE 9:									
H618B/1	PLAG	IB	OPX	IA	OPX	IB	OPX	IC	GNT
S102	57.65	2.563	50.68	1.986	51.24	1.975	51.44	1.978	37.73
Al ₂ O ₃	27.56	1.444	1.18	0.055	1.02	0.046	1.13	0.051	21.31
FeO	0.00	0.000	28.13	0.922	29.76	0.959	29.40	0.945	27.67
MnO	0.00	0.000	0.00	0.000	0.16	0.005	0.14	0.005	0.78
MgO	0.00	0.000	17.24	1.007	17.44	1.002	17.42	0.998	3.83
CaO	8.80	0.419	0.43	0.018	0.38	0.015	0.47	0.019	6.83
K ₂ O	0.27	0.015	0.00	0.000	0.00	0.000	0.00	0.000	0.24
Na ₂ O	6.54	0.563	0.00	0.000	0.00	0.000	0.00	0.000	1.63
Fe ₂ O ₃									0.00
SO ₃									0.00
TOTAL	100.81	5.004	97.66	3.987	100.00	4.002	100.00	3.997	100.00
		-8.0		-6.0		-6.0		-6.0	-12.0

SITE 9:									
H618B/2	BIOT	IA	BIOT	2	BIOT	IC			
S102	36.28	5.516	36.06	5.502	49.39	6.974			
TiO ₂	4.48	0.512	5.64	0.647	4.43	0.470			
Al ₂ O ₃	14.65	2.626	14.32	2.575	11.35	1.889			
FeO	18.87	2.400	18.03	2.300	14.17	1.674			
MgO	12.25	2.777	11.58	2.633	9.21	1.939			
CaO	0.15	0.024	0.00	0.000	0.00	0.000			
K ₂ O	8.27	1.604	9.33	1.816	7.40	1.333			
Cl	0.05	0.013	0.05	0.012	0.06	0.015			
TOTAL	95.00	15.473	95.00	15.485	96.01	14.294			
		22.0		22.0		22.0			

APPENDIX 3: (Cont.) P.10

SITE 10:

116A/1	GNT 1G	OPX 1A	CPX R	PLAG R	HBE 1A					
SiO2	38.01	3.001	51.01	1.954	43.26	1.643	57.30	2.554	41.01	6.257
Al2O3	20.95	1.949	1.25	0.056	13.61	0.609	27.73	1.457	12.95	2.329
Fe2O3	0.83	0.049	1.26	0.036	3.71	0.106	0.00	0.000	0.00	0.000
FeO	27.90	1.842	27.47	0.880	15.10	0.479	0.00	0.000	18.21	2.324
MnO	1.16	0.077	0.26	0.008	0.00	0.000	0.00	0.000	0.00	0.000
MgO	4.17	0.490	18.44	1.053	9.43	0.534	0.00	0.000	8.80	2.001
CaO	6.99	0.592	0.31	0.013	11.64	0.474	9.22	0.440	11.48	1.876
Cr2O3					0.16	0.005	0.00	0.000	0.21	0.025
K2O					0.00	0.000	0.14	0.008	2.04	0.396
Na2O					1.39	0.102	6.09	0.526	1.29	0.382
Cl					0.00	0.000	0.00	0.000	0.42	0.108
TOTAL	100.00	8.000	100.00	4.000	100.00	4.000	100.49	4.985	98.00	15.880
		-12.0		-6.0		-6.0		-8.0		23.0

SITE 10:

116A/2	GNT 3A	OPX 3A	OPX 3B	MT 3A	BIOT 3A	HBE 3A	OPAQ 4A							
S102	37.96	3.004	49.71	1.951	51.38	1.965	1.00	0.080	36.02	5.531	40.84	6.257	0.77	0.040
A1203	20.89	1.948	1.67	0.077	1.26	0.056	0.54	0.050	13.89	2.514	12.73	2.298	0.22	0.013
V203	0.00	0.000	0.00	0.000	0.00	0.000	0.58	0.037	0.00	0.000	0.00	0.000	0.22	0.009
Fe203	0.75	0.045	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	12.04	0.470
FeO	28.49	1.885	27.96	0.917	28.03	0.896	85.70	5.708	18.90	2.428	17.57	2.251	39.01	1.692
MnO	1.27	0.085	0.32	0.010	0.26	0.008	0.00	0.000	11.25	2.575	9.33	2.130	0.71	0.055
MgO	3.97	0.468	17.68	1.034	18.61	1.060	0.00	0.000	0.15	0.025	11.16	1.832	0.00	0.000
CaO	6.67	0.565	0.44	0.018	0.45	0.018	0.00	0.000	5.36	0.619	1.85	0.213	43.99	1.716
TiO2									9.20	1.802	1.91	0.372	0.07	0.004
K2O									0.00	0.000	1.44	0.426	0.00	0.000
Na2O									0.23	0.059	0.46	0.120	0.00	0.000
Cl									95.00	15.553	97.28	15.900	97.03	4.000
TOTAL	100.00	8.000	97.78	4.010	100.00	4.006	87.82	5.876	95.00	22.0	23.0	23.0	97.03	4.000
		-12.0		-6.0		-6.0		-6.0						-6.0

APPENDIX 3: (Cont.) P.11

SITE 11:			
1356/1	HBE 1B	GNT 3A	BIOT 3A
SiO ₂	40.16	6.260	38.31
TiO ₂	1.36	0.160	0.00
Al ₂ O ₃	12.79	2.349	20.89
FeO	18.37	2.394	27.97
MgO	8.43	1.959	3.79
CaO	11.34	1.893	7.68
K ₂ O	2.14	0.426	0.00
Cl	0.25	0.067	0.00
MnO			1.23
Fe ₂ O ₃			0.13
Na ₂ O	1.16	0.351	0.00
TOTAL	96.01	15.860	100.00
	23.0		8.300
		-12.0	96.43
			15.110
			22.0

SITE 11:			
1356/2	HBE 1B	GNT 3A	BIOT 3A
SiO ₂	99.57	1.989	57.09
Al ₂ O ₃	0.50	0.012	26.89
MgO	0.14	0.004	0.00
CaO	0.00	0.000	8.74
K ₂ O	0.00	0.000	0.23
Na ₂ O	0.00	0.000	6.31
TiO ₂			0.552
FeO			0.00
Cl			0.00
TOTAL	100.22	2.005	99.26
	-4.0		4.992
		-8.0	97.37
			4.954
			-8.0

APPENDIX 3: (Cont.) P.12

SITE 12:												
H623/1												
	PLAG 1A		PLAG 1B		OPX 1A		OPX 1B		QTZ 1A		GNT 1A	
SiO ₂	58.88	2.614	58.83	2.626	50.89	1.957	51.28	1.956	99.19	1.993	38.37	3.020
TiO ₂	0.00	0.00	0.00	0.000								
Al ₂ O ₃	26.60	1.391	26.23	1.380	1.78	0.080	1.81	0.081	0.36	0.009	21.01	1.949
Fe ₂ O ₃	0.00	0.000	0.00	0.000	0.21	0.006	0.35	0.010	0.00	0.000	0.20	0.012
FeO	0.00	0.000	0.00	0.000	26.92	0.866	27.07	0.862	0.00	0.000	29.13	1.917
MnO	0.00	0.000	0.00	0.000	0.28	0.009	0.20	0.005	0.00	0.000	0.78	0.052
MgO	0.00	0.000	0.00	0.000	18.70	1.072	18.90	1.072	0.00	0.000	4.98	0.584
CaO	7.96	0.378	7.78	0.372	0.25	0.010	0.23	0.010	0.00	0.000	5.53	0.466
K ₂ O	0.21	0.012	0.31	0.017	0.00	0.000	0.06	0.003	0.07	0.002	0.00	0.000
Na ₂ O	7.01	0.603	6.85	0.593								
TOTAL	100.65	4.998	100.00	4.989	99.02	4.000	100.00	4.000	99.62	2.003	100.00	8.000
		-8.0		-8.0		-8.0		-6.0		-4.0		-12.0

SITE 12:												
H623/2												
	BIOT 2A		GNT 2A		MT 2A							
SiO ₂	35.78	5.368	37.97	3.005	0.75	0.039						
TiO ₂	3.51	0.396	0.00	0.000	0.24	0.009						
Al ₂ O ₃	15.32	0.396	20.94	1.953	0.83	0.051						
FeO	16.95	2.126	30.57	2.023	87.71	3.810						
MgO	15.93	3.563	4.82	0.569	0.22	0.017						
CaO	0.23	0.037	4.10	0.348	0.00	0.000						
K ₂ O	7.14	1.366	0.00	0.000	0.00	0.000						
Na ₂ O	0.00	0.000	0.00	0.000	0.00	0.000						
Cl	0.14	0.036										
Fe ₂ O ₃			0.61	0.036	0.00	0.000						
MnO			0.98	0.066	0.00	0.000						
TOTAL	95.00	15.601	100.00	8.000	89.76	3.926						
		22.0		-12.0		-4.0						

APPENDIX 3: (Cont.) P.13

SITE 13:				
1352/1				
	GNT 2A	BIOT 2A		
SiO ₂	37.60	3.047	36.37	5.570
TiO ₂	0.00	0.000	5.00	0.576
Al ₂ O ₃	20.51	1.958	14.15	2.554
FeO	27.10	1.837	18.48	2.367
MnO	0.75	0.051	0.00	0.000
MgO	4.02	0.485	11.42	2.607
CaO	6.86	0.596	0.00	0.000
K ₂ O	0.00	0.000	9.25	1.808
Na ₂ O	0.00	0.000	0.00	0.000
Cl	0.00	0.000	0.33	0.085
TOTAL	96.84	7.974	95.00	15.567
		-12.0		22.0

SITE 13:				
1352/2				
	BIOT 2C	GNT 1A	GNT 1B	
SiO ₂	40.07	6.016	37.55	3.017
TiO ₂	1.52	0.172	0.00	0.000
Al ₂ O ₃	12.72	2.251	20.81	1.971
FeO	17.20	2.160	28.48	1.914
MnO	0.00	0.000	1.34	0.091
MgO	8.64	1.935	3.65	0.438
CaO	11.11	1.788	6.58	0.566
K ₂ O	1.95	0.374	0.00	0.000
Na ₂ O	1.23	0.357	0.00	0.000
Cl	0.55	0.139	0.00	0.000
TOTAL	95.00	15.191	98.40	7.997
		-12.0		-12.0

SITE 13:				
1352/3				
	BIOT 2C	GNT 1A	GNT 1B	
SiO ₂	36.80	5.607	37.22	3.043
TiO ₂	4.53	0.519		
Al ₂ O ₃	14.19	2.548	20.28	1.954
FeO	17.95	2.288	27.00	1.846
MnO	0.00	0.000	1.09	0.076
MgO	11.99	2.722	3.70	0.451
CaO	0.18	0.029	6.98	0.611
K ₂ O	9.13	1.775	0.00	0.000
Na ₂ O	0.00	0.000	0.00	0.000
Cl	0.23	0.059	0.00	0.000
TOTAL	95.00	15.546	96.27	7.980
		22.0		-12.0

(Cont.) P.14

SITE 13: 1352/4			
	GNT 1C	APATITE	HBE
P ₂ O ₅	0.00	41.30	0.00
SiO ₂	35.70	0.71	0.00
TiO ₂	4.75	0.00	0.00
Al ₂ O ₃	13.44	0.00	0.00
Fe ₂ O ₃	0.00	0.00	0.00
FeO	18.40	0.00	0.00
MnO	0.00	0.00	0.00
MgO	11.26	0.00	0.00
CaO	0.18	0.00	0.00
K ₂ O	9.07	0.00	0.00
Na ₂ O	0.00	0.00	0.00
Cl	0.25	0.00	0.00
TOTAL	93.04	96.44	98.00
	22.0	-12.0	23.0

SITE 14:																	
	PLAG 4F	GNT 4C	GNT 4D	CPX 4A	CPX 4B	GNT 4G	QTZ	ILM	HBE 4A								
1350/1																	
S102	56.17	38.08	3.022	38.18	3.035	52.78	1.990	51.02	1.963	37.66	3.001	95.70	1.952	1.00	0.052	40.82	6.190
T102										0.00	0.000	0.00	0.000	46.42	1.822	1.77	0.201
Al ₂ O ₃	29.67	1.537	21.46	2.006	1.957	1.64	0.073	2.09	0.095	21.07	1.978	1.27	0.030	0.51	0.031	13.72	2.453
Fe ₂ O ₃										0.33	0.020	0.00	0.000	0.00	0.000	0.00	0.000
FeO	0.00	0.000	26.17	1.736	1.757	7.96	0.251	11.11	0.357	27.41	1.826	1.71	0.029	47.64	2.079	17.52	2.222
MnO	0.00	0.000	1.33	0.089	1.29	0.087	0.00	0.000	0.00	0.97	0.066	0.00	0.000	0.16	0.007	0.00	0.000
MgO	0.00	0.000	3.58	0.424	3.68	0.436	13.13	0.738	11.60	0.665	3.99	0.474	0.35	0.011	0.20	0.094	8.91
CaO	10.94	0.515	8.21	0.698	8.37	0.713	22.60	0.913	21.90	0.903	7.44	0.635	0.15	0.003	0.07	0.004	11.43
K ₂ O	0.17	0.010								0.00	0.000	0.16	0.004	0.00	0.000	2.12	0.411
Na ₂ O	5.55	0.473	0.00	0.000	0.00	0.000	0.23	0.017	0.18	0.014	0.00	0.000	0.00	0.000	0.00	0.000	1.35
SO ₃	0.00	0.000								0.00	0.000	0.11	0.002	0.19	0.007	0.12	0.013
Cl										0.00	0.000	0.00	0.000	0.00	0.000	0.23	0.058
TOTAL	102.50	5.004	98.83	7.975	98.86	7.986	98.33	3.982	97.91	3.997	98.88	8.000	99.45	2.032	97.18	4.096	98.00
	-8.0			-12.0			-6.0		-6.0		-12.0		-4.0		-6.0		23.0

APPENDIX 3: (Cont.) P.15

SITE 15:										
1132/1										
	PLAG 2D		CPX 2B							
SiO ₂	50.68	2.303	51.80	1.960						
TiO ₂	0.00	0.000	0.00	0.000						
Al ₂ O ₃	31.68	1.697	2.19	0.097						
Fe ₂ O ₃	0.00	0.000	0.00	0.000						
FeO	0.00	0.000	8.15	0.258						
MnO	0.00	0.000	0.00	0.000						
MgO	0.00	0.000	13.71	0.773						
CaO	14.33	0.698	22.27	0.903						
K ₂ O	0.88	0.004	0.00	0.000						
Na ₂ O	3.38	0.298	0.00	0.000						
TOTAL	100.15	5.000	98.12	3.991						
		-8.0		-6.0						

SITE 15:										
1132/2										
	OPX 2B		CPX 2K		HBE 2A		BIOT 1A		OPAQUE (BRIGHT)	
SiO ₂	52.33	1.958	51.51	1.956	43.45	6.446	36.38	5.485	43.33	1.118
TiO ₂	0.00	0.000	0.00	0.000	2.05	0.228	5.37	0.608	1.62	0.031
Al ₂ O ₃	1.51	0.067	2.31	0.103	11.46	2.004	14.66	2.604	11.29	0.343
Fe ₂ O ₃	0.62	0.017	0.00	0.000	0.00	0.000				
FeO	22.48	0.704	8.03	0.255	14.32	1.777	15.45	1.947	13.60	0.293
MnO	0.59	0.019	0.15	0.005	0.00	0.000				
MgO	21.87	1.220	13.76	0.779	12.21	2.701	13.52	3.037	12.54	0.482
CaO	0.40	0.016	21.95	0.893	11.78	1.872	0.22	0.035	11.73	0.324
K ₂ O	0.00	0.000	0.00	0.000	1.54	0.292	9.24	1.776	1.54	0.051
Cl	0.00	0.000	0.00	0.000	0.16	0.040	0.17	0.044	0.19	0.008
SO ₃							0.00	0.000	0.62	0.012
Na ₂ O	0.00	0.000	0.00	0.000	1.04	0.298	0.00	0.000	1.07	0.054
TOTAL	99.80	4.000	97.70	3.992	98.00	15.658	95.00	15.537	97.51	2.716
		-6.0		-6.0		23.0		22.0		-4.0

APPENDIX 3: (Cont.) P.16

SITE 16:						
1122/1	PLAC 1B	GNT 1D	BIOT 1A			
SiO ₂	57.48	2.573	37.27	2.985	34.74	5.400
TiO ₂	0.00	0.000	0.00	0.000	3.06	0.358
Al ₂ O ₃	26.97	1.423	20.48	1.933	16.67	3.054
FeO	0.25	0.009	22.56	1.511	24.80	3.224
MnO	0.00	0.000	4.83	0.328	0.00	0.000
MgO	0.00	0.000	1.58	0.189	7.93	1.837
CaO	8.46	0.406	10.17	0.872	0.39	0.065
K ₂ O	0.25	0.015	0.07	0.008	6.32	1.253
Na ₂ O	6.60	0.573	0.22	0.035	0.60	0.180
SO ₃	0.10	0.003	0.00	0.000	0.18	0.021
Cl	0.00	0.000	0.00	0.000	0.31	0.082
Fe ₂ O ₃			2.31	0.139	0.00	0.000
TOTAL	100.11	5.002	99.49	8.000	95.00	15.472
		-8.0		-12.0		22.0

SITE 16:						
1122/2	BIOT 1E	GNT 1F				
SiO ₂	34.97	5.496	37.52	3.018		
TiO ₂	3.30	0.390	0.00	0.000		
Al ₂ O ₃	15.42	2.857	20.52	1.945		
Fe ₂ O ₃	0.00	0.000	0.00	0.000		
FeO	24.17	3.177	24.54	1.651		
MnO	0.19	0.025	4.87	0.331		
MgO	7.78	1.823	1.59	0.191		
CaO	0.22	0.036	9.60	0.828		
K ₂ O	8.26	1.657	0.00	0.000		
Na ₂ O	0.36	0.108	0.16	0.025		
SO ₃	0.00	0.000	0.18	0.011		
Cl	0.34	0.091	0.00	0.000		
TOTAL	95.00	15.659	98.98	8.000		
		22.0		-12.0		

APPENDIX 3: (Cont.) P.17

SITE 16:										
1122/3	HBE 1A	PLAG 1C	QTZ 1A	GNT 1B	BIOT 1A					
S102	38.00	6.105	57.48	2.577	99.52	1.992	37.39	3.011	35.97	5.584
TiO ₂	1.14	0.138	0.00	0.000	0.00	0.000	0.00	0.000	3.43	0.400
Al ₂ O ₃	14.01	2.653	26.98	1.426	0.39	0.009	20.39	1.935	15.90	2.908
FeO	22.24	2.989	0.00	0.000	0.00	0.000	24.77	1.668	21.97	2.852
Fe ₂ O ₃							0.70	0.043	0.00	0.000
MnO	0.17	0.023	0.00	0.000	0.00	0.000	4.37	0.298	0.00	0.000
MgO	5.21	1.248	0.18	0.012	0.10	0.003	1.68	0.202	8.09	1.872
CaO	10.87	1.872	8.44	0.405	0.00	0.000	9.78	0.843	0.16	0.027
K ₂ O	2.13	0.437	0.28	0.016	0.00	0.000	0.00	0.000	8.95	1.773
Na ₂ O	1.18	0.367	6.46	0.561	0.00	0.000	0.00	0.000	0.22	0.065
Cl	0.57	0.154	0.00	0.000	0.00	0.000	0.00	0.000	0.32	0.083
TOTAL	95.52	15.986	99.83	4.998	100.00	2.004	99.08	8.000	95.00	15.564
	23.0		-8.0		-4.0		-12.0		22.0	

SITE 16:										
1122/4	PLAG 1D	GNT 1A	BIOT 1B	HBE 2A						
S102	58.67	2.621	37.67	2.999	35.61	5.559	36.85	6.010		
TiO ₂	0.00	0.000	0.00	0.000	3.38	0.397	0.81	0.099		
Al ₂ O ₃	26.23	1.381	20.52	1.926	15.59	2.869	14.59	2.803		
Fe ₂ O ₃	0.00	0.000	2.51	0.150						
FeO	0.00	0.000	22.85	1.522	23.02	3.006	22.67	3.092		
MnO	0.00	0.000	4.39	0.296	0.00	0.000	0.22	0.031		
MgO	0.00	0.000	1.75	0.208	8.11	1.887	4.73	1.149		
CaO	7.82	0.374	9.76	0.833	0.00	0.000	10.92	1.908		
K ₂ O	0.25	0.014	0.10	0.010	8.93	1.779	2.31	0.480		
Na ₂ O	7.06	6.11	0.30	0.046	0.00	0.000	1.00	0.317		
Cl	0.05	0.004	0.07	0.010	0.35	0.092	0.72	0.198		
TOTAL	100.07	5.005	99.92	8.000	95.00	15.591	94.81	16.086		
	-8.0		-12.0		22.0		23.0			

APPENDIX 3: (Cont.) P.18

SITE 16:													
1122/5													
	HBE IF			HBE 4A									
SiO ₂	38.28	6.093	38.62	6.264									
TiO ₂	1.08	0.129	0.00	0.000									
Al ₂ O ₃	14.27	2.677	13.06	2.496									
FeO	22.37	2.977	22.70	3.079									
MnO	0.15	0.021	0.30	0.041									
MgO	5.31	1.259	5.46	1.320									
CaO	10.99	1.874	10.94	1.901									
K ₂ O	2.23	0.453	2.13	0.440									
Na ₂ O	1.19	0.367	1.06	0.332									
Cl	0.62	0.167	0.53	0.146									
TOTAL	96.49	16.016	94.80	16.020									
		23.0		23.0									

SITE 16:																				
1122/6 (Traverse)																				
	HBD RIM R			HBD MATRIX			BIOT MATRIX			FLAG 1			BIOT MATRIX 2		QTZ 1		KSP 1		HBE CORE	
SiO ₂	39.47	6.078	44.06	6.617	38.77	5.754	60.30	2.600	36.60	5.640	99.51	1.985	63.71	3.002	39.81	6.157				
TiO ₂	1.02	0.118	0.80	0.090	3.68	0.410	0.00	0.000	4.01	0.464	0.00	0.000	0.00	0.000	1.41	0.164				
Al ₂ O ₃	14.90	2.705	14.17	2.507	16.80	2.939	27.57	1.401	15.35	2.787	0.62	0.015	18.25	1.014	13.71	2.499				
FeO	23.51	3.028	22.19	2.787	21.62	2.683	0.00	0.000	23.45	3.023	0.00	0.000	0.00	0.000	23.09	2.986				
MnO	0.32	0.042	0.26	0.033	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.21	0.028				
MgO	5.25	1.205	4.34	0.972	6.70	1.483	0.15	0.010	7.23	1.660	0.20	0.006	0.00	0.000	5.70	1.315				
CaO	11.47	1.892	10.43	1.679	1.22	0.194	8.51	0.393	0.50	0.083	0.00	0.000	0.19	0.010	11.31	1.875				
K ₂ O	2.28	0.447	2.32	0.445	8.23	1.557	0.28	0.015	8.58	1.686	0.12	0.003	14.38	0.864	2.22	0.439				
Na ₂ O	1.08	0.323	0.91	0.264	0.86	0.248	6.88	0.575	0.00	0.000	0.00	0.000	0.00	0.000	1.24	0.372				
Cl	0.66	0.173	0.71	0.181	0.29	0.073	0.00	0.000	0.28	0.074	0.00	0.000	0.00	0.000	0.63	0.166				
TOTAL	99.95	16.009	100.18	15.575	98.17	15.342	103.69	4.995	96.00	15.419	100.45	2.009	97.26	4.956	99.35	16.001				
		23.0		23.0		22.0		-8.0		22.0		-4.0		-8.0		23.0				

APPENDIX 3: (Cont.) P.19

SITE 16:

1122/6 (Traverse) (Continued)

	HBD RIM	HBD RIM R	HBD 3	BIOT MATRIX	FSP MATRIX	HBD MATRIX	PLAG MATRIX	PLG R								
S102	52.43	7.222	41.67	6.294	39.21	6.101	35.51	5.520	65.29	2.989	40.71	6.253	63.73	2.725	59.31	2.633
TiO2	0.34	0.035	0.98	0.111	1.03	0.121	3.90	0.456	0.00	0.000	0.84	0.097	0.00	0.000	0.00	0.000
Al2O3	19.86	3.225	15.87	2.825	14.65	2.687	15.12	2.769	19.03	1.027	15.39	2.096	25.35	1.278	26.19	1.370
FeO	10.76	1.239	20.82	2.629	22.97	2.988	24.30	3.158	0.00	0.000	21.87	2.810	0.00	0.000	0.00	0.000
MnO	0.00	0.000	0.18	0.023	0.22	0.029	0.00	0.000	0.00	0.000	0.25	0.033	0.00	0.000	0.00	0.000
MgO	2.42	0.496	4.72	1.064	5.27	1.221	7.81	1.810	0.00	0.000	4.51	1.032	0.00	0.000	0.00	0.000
CaO	8.64	1.276	10.90	1.763	11.30	1.885	0.20	0.032	0.45	0.022	10.57	1.740	7.39	0.339	7.50	0.357
K2O	1.08	0.190	2.03	0.390	2.29	0.454	8.81	1.747	14.69	0.858	3.38	0.662	0.20	0.011	0.25	0.014
Na2O	4.06	1.083	1.90	0.555	1.16	0.350	0.14	0.043	0.72	0.064	1.17	0.349	6.97	0.578	7.35	0.632
Cl	0.32	0.076	0.59	0.151	0.75	0.197	0.35	0.092	0.00	0.000	0.81	0.212	0.00	0.000	0.00	0.000
TOTAL	99.92	14.843	99.65	15.806	98.85	16.033	96.14	15.627	100.18	4.959	99.50	15.974	103.65	4.930	100.59	5.005
	23.0		23.0		23.0		22.0		-8.0		23.0		-8.0		-8.0	

SITE 16:

1122/6 (Traverse) (Continued)

	PLAG MEGA	QTZ RIBBON	PLAG
SiO2	57.56	99.10	59.31
Al2O3	26.76	1.417	26.19
MgO	0.00	0.09	0.00
CaO	8.50	0.00	7.50
K2O	0.21	0.11	0.25
Na2O	6.61	0.00	7.35
Cl	0.00	0.00	0.00
TOTAL	99.65	100.59	100.59
	-8.0	-4.0	-8.0

APPENDIX 3: (Cont.) P.20

SITE 17:
1163/1

	OPX 1A	GNT 1A	OPX 1B	MT 1A	PLAG 1A	HBE 4A						
SiO ₂	51.33	1.961	38.21	3.014	50.85	1.963	1.06	0.054	52.58	2.388	40.25	6.248
Al ₂ O ₃	1.29	0.058	21.02	1.955	1.39	0.063	1.52	0.091	30.14	1.614	12.91	2.362
Fe ₂ O ₃	0.67	0.019	0.29	0.017	0.36	0.010	0.00	0.000	0.00	0.000	0.00	0.000
FeO	26.56	0.849	26.92	1.776	27.49	0.888	86.50	3.669	0.00	0.000	16.67	2.164
MnO	0.54	0.018	0.90	0.060	0.40	0.013	0.00	0.000	0.00	0.000	0.00	0.000
MgO	18.94	1.079	3.83	0.450	18.19	1.047	0.25	0.019	0.00	0.000	9.15	2.117
CaO	0.40	0.016	8.62	0.728	0.38	0.016	0.00	0.000	12.46	0.606	11.17	1.858
K ₂ O	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.24	0.014	2.13	0.423
Na ₂ O	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	4.32	0.380	1.29	0.388
TiO ₂	0.00	0.000	0.00	0.000	0.00	0.000	0.14	0.005	0.00	0.000	1.78	0.208
V ₂ O ₃					0.00	0.000	0.94	0.038	0.00	0.000	0.00	0.000
Cl					0.00	0.000	0.00	0.000	0.00	0.000	0.39	0.103
TOTAL	99.73	4.000	98.78	8.000	99.06	4.000	90.41	3.876	99.73	5.002	95.76	15.871
	-6.0		-12.0		-6.0		-4.0		-8.0		23.0	

SITE 18:
MH2A/1

MH2A/1	PLAG 1B	OPX 1A	GNT 1A	GNT 1B				
S102	55.49	2.448	51.67	1.941	38.33	2.958	38.05	2.984
T102			0.00	0.000	0.00	0.000	0.00	0.000
Al203	29.92	1.556	1.53	0.068	21.72	1.975	20.98	1.939
Fe2O3			1.81	0.051	1.86	0.108	1.58	0.093
FeO	0.00	0.000	25.23	0.793	26.46	1.708	27.02	1.772
MnO			0.22	0.007	0.99	0.065	1.10	0.073
MgO	0.00	0.000	20.13	1.127	5.50	0.633	4.81	0.562
CaO	11.52	0.545	0.36	0.014	6.68	0.553	6.86	0.576
K2O	0.26	0.015						
Na2O	5.11	0.437	0.00	0.000	0.00	0.000	0.00	0.000
TOTAL	102.31	5.000	100.94	4.000	101.54	8.000	100.40	8.000
		-8.0		-6.0		-12.0		-12.0

APPENDIX 3: (Cont.) P.21

SITE 18:

MH2A/2	CPX 1C		GNT 1C		GNT 1D		PLAG 1C		CPX 1D	
S102	51.29	1.954	37.98	2.978	38.21	2.995	52.26	2.391	51.29	1.950
TiO2	0.00	0.000								
Al2O3	2.06	0.092	20.83	1.924	21.01	1.940	29.90	1.612	2.50	0.112
Fe2O3	0.01	0.000	2.04	0.121	1.18	0.069	0.00	0.000	0.00	0.000
FeO	9.55	0.304	26.15	1.715	26.26	1.721	0.00	0.000	9.46	0.301
MnO	0.00	0.000	1.06	0.071	0.94	0.062	0.00	0.000	0.00	0.000
MgO	13.04	0.741	5.36	0.626	5.45	0.637	0.00	0.000	12.79	0.725
CaO	22.27	0.909	6.75	0.567	6.84	0.575	12.48	0.611	22.28	0.907
Na2O	0.00	0.000	0.00	0.000	0.00	0.000	4.09	0.363	0.00	0.000
K2O			0.00	0.000	0.00	0.000	0.23	0.013	0.00	0.000
TOTAL	98.22	4.000	100.17	8.000	99.89	8.000	98.96	4.991	98.32	3.994
		-6.0		-12.0		-12.0		-8.0		-6.0

SITE 19:

MH1C/1	OPX 2A		GNT 2A		GNT 2AR		CPX 2A		GNT 2C		PLAG 2A	
S102	49.64	1.922	34.36	2.843	37.81	2.949	49.92	1.926	37.85	2.974	55.63	2.495
Al2O3	1.87	0.085	16.15	1.575	21.25	1.954	2.91	0.132	21.25	1.968	28.63	1.513
Cr2O3	0.00	0.000	13.12	0.858	0.00	0.000						
Fe2O3	2.42	0.071	0.00	0.000	3.26	0.191	1.07	0.031	1.41	0.083	0.00	0.000
FeO	27.40	0.887	21.79	1.508	25.50	1.664	10.27	0.331	26.73	1.756	0.00	0.000
MnO	0.34	0.011	0.90	0.063	1.25	0.082	0.00	0.000	1.18	0.079	0.00	0.000
MgO	17.45	1.007	3.56	0.440	4.41	0.513	11.34	0.652	4.37	0.511	0.00	0.000
CaO	0.41	0.017	6.60	0.585	7.20	0.602	21.84	0.903	7.46	0.628	10.15	0.488
K2O	0.00	0.000	0.14	0.015	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
SO3	0.00	0.000	0.21	0.013	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Cl	0.00	0.000	0.14	0.019	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
TiO2							0.10	0.003	0.00	0.000	0.00	0.000
TOTAL	99.53	4.000	97.23	7.962	100.97	8.000	97.73	4.000	100.25	8.000	100.30	5.000
		-6.0		-12.0		-12.0		-6.0		-12.0		-8.0

APPENDIX 3: (Cont.) P. 22

SITE 20:													
1305/1													
	OPX 2B	CPX 2A	CPX 2B	OPX 2C	OPX 2D	ILM 2A	HBD 2A	PLAG 2A					
SiO ₂	50.22	1.948	51.40	1.938	49.62	1.940	49.64	1.939	0.15	0.008	40.70	6.200	52.54
Al ₂ O ₃	1.55	0.071	2.59	0.113	1.48	0.068	1.62	0.075	0.17	0.011	13.47	2.419	29.79
Fe ₂ O ₃	1.16	0.034	0.49	0.034	1.78	0.052	1.60	0.047	0.00	0.000	0.00	0.000	0.00
FeO	28.03	0.909	11.81	0.373	10.76	0.340	28.27	0.923	47.52	2.111	17.57	2.239	0.00
MnO	0.45	0.015	0.00	0.000	0.50	0.017	0.44	0.015	0.33	0.015	0.00	0.000	0.00
MgO	17.49	1.011	11.55	0.651	17.06	0.994	16.93	0.986	0.78	0.061	9.00	2.043	0.00
CaO	0.30	0.013	21.96	0.889	0.37	0.016	0.37	0.016	0.00	0.000	11.52	1.880	11.81
Na ₂ O	0.00	0.000	0.20	0.015	0.00	0.000	0.00	0.000	0.00	0.000	1.36	0.403	4.71
TiO ₂							0.00	0.000	47.34	1.891	1.74	0.199	0.00
K ₂ O							0.00	0.000	0.00	0.000	2.18	0.424	0.22
Cl							0.00	0.000	0.00	0.000	0.47	0.121	0.00
TOTAL	99.19	4.000	100.00	4.000	98.77	4.000	98.87	4.000	96.28	4.096	98.00	15.926	99.07
	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	23.0	-8.0	-8.0

SITE 20:													
1305/1 (Continued)													
	PLAG 3A	CPX 3AR	CPX 3B	GNT 3B	MT 4	QTZ							
SiO ₂	55.62	2.488	50.64	1.951	50.83	1.949	37.70	2.983	0.63	0.032	100.08	1.989	
Al ₂ O ₃	28.67	1.511	2.02	0.092	2.09	0.095	21.32	1.988	1.07	0.064	0.37	0.009	
Fe ₂ O ₃			0.80	0.023	0.74	0.021	1.14	0.068					
FeO	0.00	0.000	10.20	0.329	10.31	0.331	25.34	1.677	88.37	3.746	0.00	0.000	
MnO			0.20	0.007	0.11	0.004	1.57	0.105	0.00	0.000	0.00	0.000	
MgO	0.24	0.016	11.81	0.678	11.79	0.674	4.25	0.501	0.38	0.028	0.15	0.004	
CaO	10.41	0.499	21.87	0.903	22.18	0.912	7.75	0.657	0.00	0.000	0.00	0.000	
K ₂ O	0.25	0.015	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.08	0.002	
Na ₂ O	5.43	0.471	0.23	0.017	0.20	0.015	0.14	0.022	0.17	0.016	0.14	0.005	
Cl			0.00	0.000	0.00	0.000							
TiO ₂									0.41	0.016	0.00	0.000	
V ₂ O ₅									0.42	0.017	0.00	0.000	
TOTAL	100.63	4.999	97.77	4.000	98.25	4.000	99.20	8.000	91.44	3.920	100.82	2.010	
	-8.0	-8.0	-6.0	-6.0	-6.0	-6.0	-12.0	-12.0	-4.0	-4.0	-4.0	-4.0	

APPENDIX 3: (Cont.) P.23

SITE 21:		PLAC 2B		CPX 2B	
MH3B/1					
SiO ₂	55.07	2.485	51.45	1.951	
Al ₂ O ₃	28.55	1.518	2.28	0.102	
Fe ₂ O ₃	0.00	0.000	0.38	0.011	
FeO	0.00	0.000	9.74	0.309	
MgO	0.00	0.000	12.35	0.698	
CaO	10.60	0.512	22.52	0.915	
K ₂ O	0.22	0.013	0.00	0.000	
Na ₂ O	5.34	0.467	0.20	0.015	
TOTAL	99.78	4.995	98.92	4.000	
		-8.0		-6.0	

SITE 21:		GNT 3A		GNT 3B		CPX 3A		CPX 3B	
MH3B/2									
SiO ₂	38.11	2.965	37.69	2.949	61.28	2.216	50.34	1.936	
Al ₂ O ₃	21.35	1.958	21.32	1.966	1.92	0.082	2.58	0.117	
Fe ₂ O ₃	2.29	0.134	2.30	0.136	0.00	0.000	1.38	0.040	
FeO	25.89	1.685	26.20	1.714	8.09	0.245	9.56	0.307	
MnO	0.72	0.048	0.71	0.047	0.00	0.000	0.00	0.000	
MgO	5.02	0.582	4.33	0.505	9.44	0.509	11.62	0.666	
CaO	7.26	0.605	8.14	0.682	17.60	0.682	21.95	0.905	
Na ₂ O	0.15	0.023	0.00	0.000	0.27	0.019	0.39	0.029	
TOTAL	100.79	8.000	100.69	8.000	98.60	3.752	97.82	4.000	
		-12.0		-12.0		-6.0		-6.0	

APPENDIX 4

Time picks, cumulative thickness and lithological proportions adopted for subsidence calculations

Sequence	Stratigraphic Unit	Symbol	Cumulative Depth (ft)	Age (Ma) (base)	Lithological Proportions (%)			
					Sandstone	Siltstone	Shale	Carbonate
9	Brewer Conglomerate Hermannsburg Sst Parke Siltstone	B	4346.0	368	1.0	0.0	0.0	0.0
		H	7140.0	372	0.93	0.0	0.07	0.0
		P	7299.0	385	0.53	0.0	0.47	0.0
		U/C	7299.1	400				
8	Mereenie Sandstone	M	9613.0	428	0.92	0.0	0.08	0.0
		U/C	9613.1	468				
7	Carmichael Sandstone	C	10060.0	470	0.82	0.0	0.18	0.0
		U/C	10060.1	471				
6	Stokes Siltstone Stairway Sandstone Horn Valley Siltstone Pacoota Sandstone Upper Goyder Fm	S	11613.0	476	0.06	0.94	0.00	0.0
		R	12358.0	478	0.48	0.28	0.24	0.0
		V	12603.0	482	0.08	0.04	0.74	0.14
		F	13738.0	506	0.90	0.10	0.00	0.00
		G2	13943.0	508	0.08	0.24	0.33	0.35
		U/C	13943.1	518				
5	Lower Goyder Fm Shannon Fm	G1	14111.0	523	0.00	0.28	0.35	0.37
		N2	14732.0	525	0.02	0.00	0.38	0.60
		N1	15349.0	528	0.00	0.15	0.58	0.27
		U	16133.0	534	0.00	0.90	0.05	0.05
	Giles Creek Domomite	K3	16652.0	537	0.00	0.35	0.05	0.60
		K2	16983.0	539	0.00	0.00	0.28	0.72
		K1	17098.0	540	0.00	0.00	0.85	0.15
		D2	17133.0	540.5	0.034	0.33	0.33	0.00
	Chandler Fm	D1	18033.0	555	0.90	0.00	0.10	0.00
		U/C	18033.1	563				
4	Todd River Dolomite Arumbera Sandstone 3&4	T	18112.0	570	0.05	0.00	0.90	0.05
		A2	18338.0	575	0.70	0.20	0.10	0.00
		A1	18499.0	585	0.40	0.40	0.20	0.00
		U/C	18499.1	605				
	Arumbera Sandstone 1&2	Z4	18709.0	609	0.75	0.15	0.10	0.00
		Z3	18786.0	610	0.80	0.10	0.10	0.00
		Z2	18896.0	613	0.40	0.25	0.35	0.00
		Z1	19089.0	625	0.50	0.30	0.20	0.00
		U/C	19089.1	630	0.50	0.30	0.20	0.00

APPENDIX 4 (Cont.)

Sequence	Stratigraphic Unit	Symbol	Cumulative Depth	Age	Lithological Proportions (%)			
					Sandstone	Siltstone	Shale	Carbonate
3	Julie Fm Pertatataka Fm Olympic Fm	J	19227.0	635	0.02	0.49	0.49	0.00
		E	21020.0	655	0.10	0.45	0.45	0.00
		U/C	21020.1	660				
		O	21552.0	680	0.30	0.60	0.00	0.10
		U/C	21552.1	705				
2	Aralka Fm (& Limbla Member) Areyonga Fm	L2	22023.0	730	0.70	0.30	0.00	0.00
		L1	24891.0	735	0.00	0.60	0.20	0.20
		Y	25563.0	760	0.10	0.01	0.79	0.01
		U/C	25563.1	825				
1	Bitter Springs Fm Heavitree Quartzite	I	29400.0	850	0.11	0.04	0.28	0.57
		Q	30253.0	865	0.98	0.01	0.01	0.00
		U/C	30253.1	900				

BASEMENT