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Geological–tectonic framework of Solomon Islands, SW Pacific: crustal accretion and growth within an intra-oceanic setting

M.G. Petterson [a,*], T. Babbs [b], C.R. Neal [c], J.J. Mahoney [d], A.D. Saunders [b], R.A. Duncan [e], D. Tolia [a], R. Magu [a], C. Qopoto [a], H. Mahoa [a], D. Natogga [a]

[a] *Ministry of Energy Water and Mineral Resources, Water and Mineral Resources Division, P.O. Box G37, Honiara, Solomon Islands*
[b] *Department of Geology, University of Leicester, University Road, Leicester LE1 7RH, UK*
[c] *Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, Indiana 46556, USA*
[d] *School of Ocean and Earth Science and Technology, University of Hawaii, 2525 Correa Road, Honolulu, Hawaii 96822, USA*
[e] *College of Oceanographic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon 97331, USA*

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Abstract

The Solomon Islands are a complex collage of crustal units or terrains (herein termed the 'Solomon block') which have formed and accreted within an intra-oceanic environment since Cretaceous times. Predominantly Cretaceous basaltic basement sequences are divided into: (1) a plume-related Ontong Java Plateau terrain (OJPT) which includes Malaita, Ulawa, and northern Santa Isabel; (2) a 'normal' ocean ridge related South Solomon MORB terrain (SSMT) which includes Choiseul and Guadalcanal; and (3) a hybrid 'Makira terrain' which has both MORB and plume/plateau affinities. The OJPT formed as an integral part of the massive Ontong Java Plateau (OJP), at c. 122 Ma and 90 Ma, respectively, was subsequently affected by Eocene–Oligocene alkaline and alnoitic magmatism, and was unaffected by subsequent arc development. The SSMT initially formed within a 'normal' ocean ridge environment which produced a MORB-like basaltic basement through which two stages of arc crustal growth subsequently developed from the Eocene onwards. The Makira terrain records the intermingling of basalts with plume/plateau and MORB affinities from c. 90 Ma to c. 30 Ma, and a contribution from Late Miocene–present-day arc growth. Two distinct stages of arc growth occurred within the Solomon block from the Eocene to the Early Miocene (stage 1) and from the Late Miocene to the present day (stage 2). Stage 1 arc growth created the basement of the central part of the Solomon block (the Central Solomon terrain, CST), which includes the Shortland, Florida and south Isabel islands. Stage 2 arc growth led to crustal growth in the west and south (the New Georgia terrain or NGT) which includes Savo, and the New Georgia and Russell islands. Both stages of arc growth also added new material to pre-existing crustal units within other terrains. The Solomon block terrane collage records the collision between the Alaska sized OJP and the Solomon arc. Initial contact possibly first occurred some 25–20 Ma but it is only since around 4 Ma that the OJP has more forcefully collided with the Solomon arc, and has been actively accreting since that time, continuing to the present day. We present a number of tectonic models in an attempt to understand the mechanism of plateau accretion. One model depicts the OJP as splitting in two with the upper 4–10 km forming an imbricate stack verging to the northeast, over which the Solomon arc is overthrust, whilst deeper portions of the OJP (beneath a critical detachment surface) are subducted. The subduction of young (<5 Ma), hot, oceanic lithosphere belonging to the Woodlark basin at the SSTS has resulted in a sequence of tectonic phenomena including: the production of unusual magma compositions (e.g. Na–Ti-rich basalts, and an abundance of picrites); an anomalously small

* Corresponding author. Present address: British Geological Survey, West Mains Road, Edinburgh EH9 3LA, UK; E-mail: mgp@wpo.NERC.ac.uk

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arc–trench gap between the SSTS and the Quaternary–Recent arc front; calc-alkaline arc growth within the downgoing Woodlark basin lithospheric plate as a consequence of calc-alkaline magma transfer along leaky NE–SW-trending faults; rapid fore-arc uplift; and rapid infilling of intra-arc basins. The present-day highly oblique collision between the Pacific and Australian plates has resulted in the formation of rhombohedral intra- and back-arc basins.

Keywords: terrains; ocean plateaus; island arcs; accretion; basement geochemistry; Solomon Islands

1. Background and context: a 'terrain' framework for Solomon Islands

Ever since the work of Coleman during the 1960's and 1970's (e.g. Coleman, 1965, 1966, 1970) his 'geological province model' (see below) has been the template for the broad geological framework of Solomon Islands. The Coleman province model has been much cited and is a great testament to Dr. Coleman, not least that the model has remained relevant for so long. However, since the 1970's and 1980's, a wealth of new geological, geophysical, geochronological, and geochemical data have become available. This paper draws particularly on data which have been derived from recent geological surveys by the Mineral Resources Division of the Solomon Islands Government and geochemical research undertaken since 1992 by several of the present authors.

The model presented below uses the concept of a 'terrain' as opposed to a terrane sensu stricto. We use the term 'terrain' to subdivide Solomon Islands into a number of geological sub-units which are distinct from one another in terms of gross basement geology, arc development, and geochronology, and can be defined by relatively simple geochemical, tectonic, and geological criteria. Some of the 'terrains' are 'terranes' sensu stricto in the sense that they have had a unique geological history and are separated from other 'terrains' by terrane-bounding faults. Other terrains have less well defined relationships with their neighbouring terrains. The value of using the terrain approach is that it allows a geological framework model of Solomon Islands to be devised which reflects the dynamic tectonic evolution and terrain accretion processes which have been involved in forming the present-day Solomon Island Archipelago. The model has several immediate applications to research areas such as mineral exploration and metallogenic modelling, and intra-oceanic tectonics.

2. Tectonic setting of the Solomon Islands

The Solomon Islands form an archipelago situated between longitudes 156° to 170°E, and latitudes 5° to 12°S (Fig. 1). This paper concentrates on the larger islands which form the characteristic NW–SE-trending double chain of islands comprising Choiseul, the New Georgia Group, Santa Isabel, Guadalcanal, Malaita and Makira (San Cristobal). The eastern Santa Cruz Group is, in geological terms, part of the Vanuatuan arc system and is excluded from this discussion. The islands of New Britain, Bougainville, Solomon Islands, and Vanuatu are termed the 'Greater Melanesian Arc' (e.g. Kroenke, 1984) which marks the collisional zone between the Australian and Pacific plates (Fig. 1).

The Solomon Islands are a collage of crustal units with discrete and complex geological histories, and which form an upstanding topographic block measuring 1200 km by 250 km, oriented NW–SE, and surrounded by relatively deep ocean floor to the northeast and southwest (Fig. 1). *The Solomon block* itself comprises a series of islands and submarine basins. The sedimentary basins have accumulated sediment thicknesses of up to 4–7 km (Coleman, 1989). The bulk of the basin sediment fill is younger than Pliocene in age, although older Eocene sediments are present (Coleman, 1989). Auzende et al. (1994) suggest that basin development accelerated during Pliocene–Recent times as a result of increased transpression between the Australian and Pacific plates.

The Solomon block is bounded by two trench systems: the *Vitiaz trench* (locally named the North Solomon trench) to the northeast and the *New Britain–San Cristobal* trench (in this paper termed the *South Solomon trench system or SSTS*) to the southwest (Fig. 1). The Vitiaz trench extends for a distance of some 2500–3000 km and attains depths

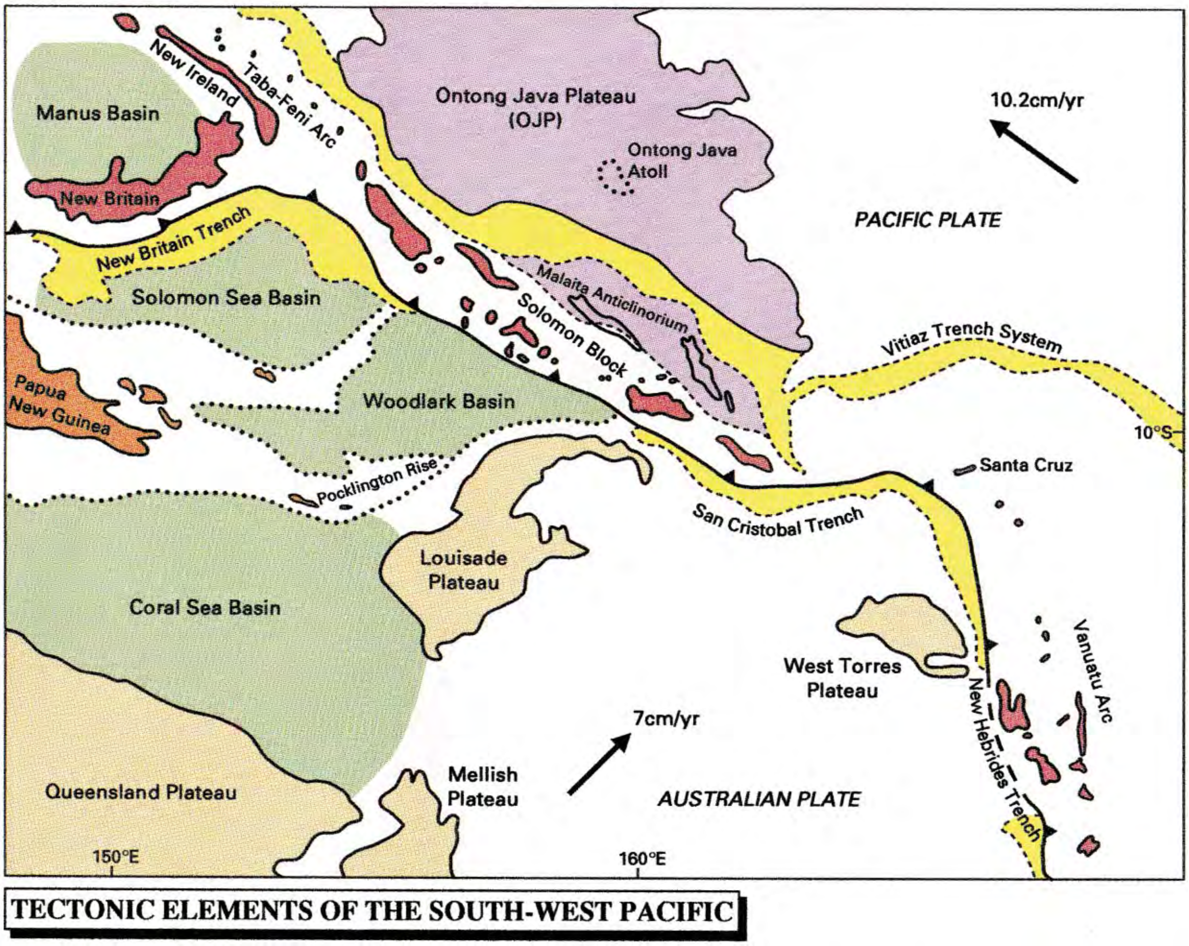

Fig. 1. The Solomon Islands form an island archipelago and are part of the Greater Melanesian arc system. The Malaita anticlinorium is an obducted part of the Ontong Java Plateau (OJP). The bulk of the OJP is situated north of the Vitiaz trench. A number of young ocean basins (e.g. the Woodlark basin) and oceanic 'plateaus' of variable origin are situated to the south and west of the Solomons. Note the highly oblique angle of collision between the Pacific and Australian plates.

of 3000–6000 m. The SSTS comprises two deep trenches (up to 8–9000 m deep in the New Britain area and 7500 m in the San Cristobal/Makira area, Kroenke et al., 1983) linked by a much shallower and ill defined trench system between the islands of Guadalcanal and Bougainville (maximum depths of 2500–5000 m). The Vitiaz trench used to be considered to be relatively inactive seismically, and was interpreted as a relict subduction-related trench which was active between the Eocene and Early Miocene becoming inactive when the Ontong Java Plateau began impinging on the Solomon block at some 25–20 Ma (e.g. Coleman and Kroenke, 1981; Kroenke, 1984; Yan and Kroenke, 1993). However, seismic and swath mapping evidence presented by Cooper and Taylor (1984), Sopacmaps (1994), Auzende et al. (1996) and most recently by Miura et al. (1996) and Mann et al. (1998) have demonstrated that south-west-directed subduction beneath the Vitiaz trench is still proceeding. The SSTS marks the site of northeast-directed subduction of the Australian plate beneath the Pacific plate, with the San Cristobal Benioff zone recording subduction to 700 km (Dunkley, 1983; Cooper and Taylor, 1984; Petterson, 1995).

A number of relatively small and young ocean basins are situated to the south and west of the

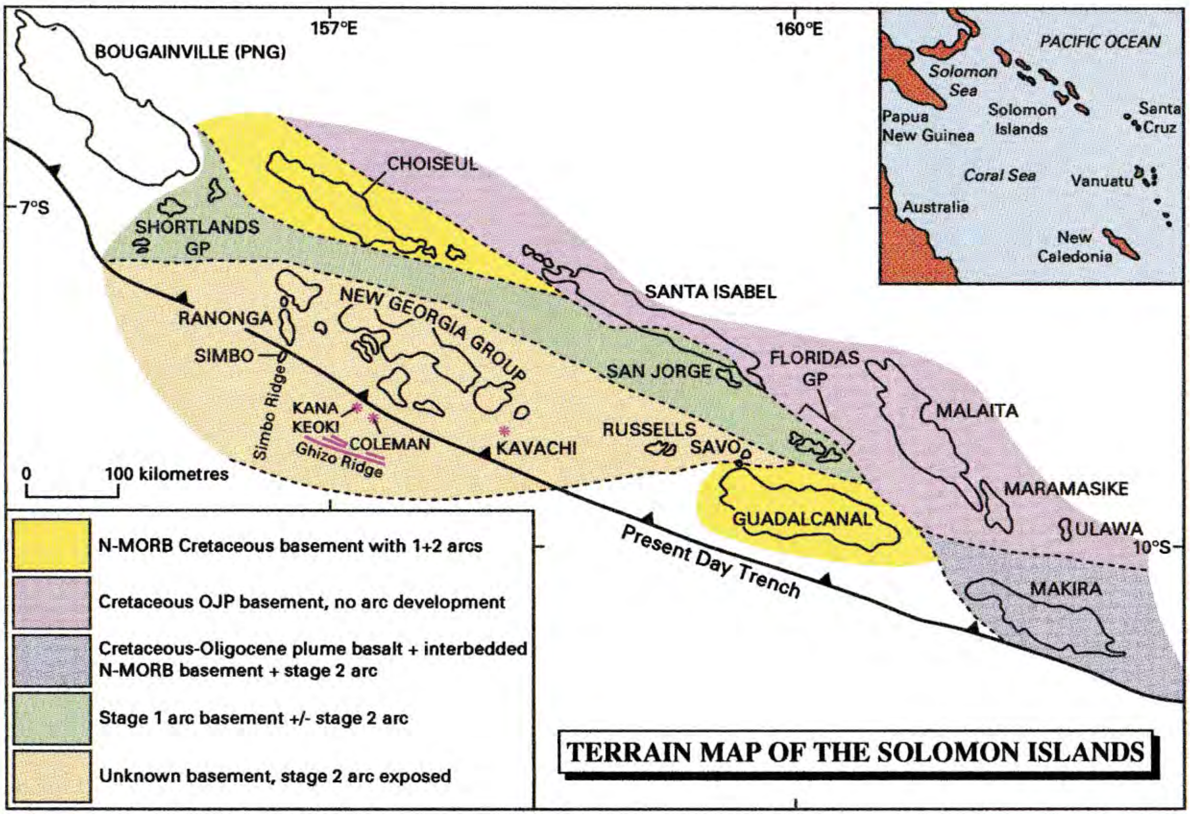

Fig. 2. Terrain model of Solomon Islands. Five crustal units are identified on the basis of distinctive lithology, age, and geochemistry of basement sequences and presence/absence of arc sequences. See text for details.

Solomon block, such as the Solomon Sea and Manus basins (Figs. 1 and 2). *The Woodlark basin* is particularly important to the Solomon terrains model as a number of large, geochemically evolved andesitic to dacitic volcanic structures are present within the Woodlark basin, south of the SSTS (e.g. the Simbo and Ghizo ridges and Coleman and Kan Keoki seamounts described by Taylor and Exon, 1987 and Crook and Taylor, 1994). The Woodlark basin is an actively spreading marginal basin situated at the northern edge of the Australian plate. The boundary between the Woodlark basin and the Solomon block is a trench–trench–transform triple margin. Spreading began in the Woodlark basin at some 5 Ma and unusual high-Ti and high-Na basalts have been dredged from the basin (Johnson et al., 1987; Perfit et al., 1987; Staudigel et al., 1987; Crook and Taylor, 1994). Subduction of the Woodlark basin beneath the Solomon block has resulted in: (1) tectonic uplift of the Solomon block; (2) the production of picrites in the New Georgia area; (3) leakage of calc-alkaline material from source regions north of the SSTS to the Woodlark basin itself (south of the SSTS) through NE–SW-trending transform faults; (4) an anomalously small arc–trench gap (for example the active Kavachi volcano is situated only some 30 km north of the SSTS; Johnson and Tuni, 1987) and; (5) increased coupling between the Pacific and Australian plates (e.g. Dunkley, 1983, 1984; Crook and Taylor, 1994; Petterson et al., 1997).

The Alaska-sized, Cretaceous *Ontong Java Plateau* (OJP) is the largest ocean plateau in the world, and is situated mainly to the north of the Solomon block (Fig. 1). The OJP is estimated to be some 36–42 km thick (Furumoto et al., 1970; Hussong et al., 1979) and broadly has a similar crustal seismic structure to 'normal' Pacific ocean crust, but thickened by a factor of five (Hussong et al., 1979;

Neal et al., 1997). This structure has been interpreted as comprising an upper basaltic lava-sill pile with a pelagic sediment cover, and a lower gabbro granulite (± garnet) which may be locally eclogitic (Rudnick and Jackson, 1995; Neal et al., 1997). The bulk of the OJP represents high volume, high emplacement rate, plume-related magmatic events dated at 122 Ma and 90 Ma (Mahoney et al., 1993; Bercovici and Mahoney, 1994; Tejada et al., 1996; Neal et al., 1997). As will be discussed below, recent geological and geochemical data have proven that the Malaita anticlinorium is compositionally identical to the OJP and represents an obducted part of the OJP (Babbs, 1997; Petterson et al., 1997; Neal et al., 1997).

3. A new geological framework for Solomon Islands

The geological terrain model presented in this paper is a development of the geological province model of Coleman and others (Fig. 3; Coleman, 1965, 1966, 1970; Coleman and Kroenke, 1981). Coleman divided the Solomon Islands into four

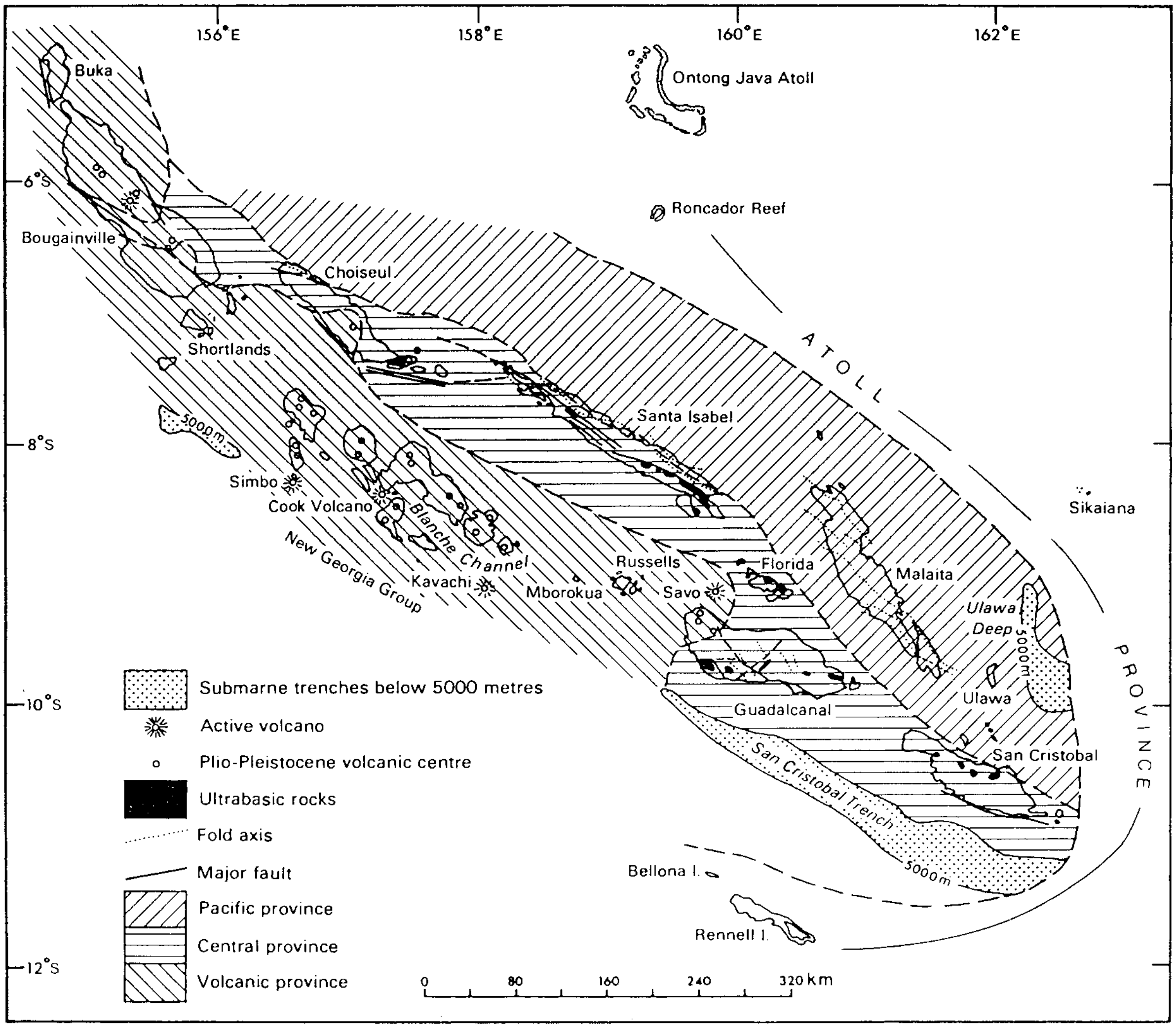

Fig. 3. Original Coleman (Coleman, 1965, 1966, 1970) geological province model of the Solomon Islands. See text for discussion.

Table 1
Average geochemical analyses of basalts from Malaita, Ulawa, Makira, Guadalcanal, and Choiseul

	Malaita ($N = 157$)	Ulawa ($N = 10$)	Makira (Plateau) ($N = 25$)	Makira (Morb) ($N = 13$)	Guadalcanal ($N = 7$)	Choiseul ($N = 14$)
SiO_2	50.09	50.44	50.20	50.25	52.23	50.01
TiO_2	1.56	1.24	1.37	1.57	0.98	1.45
Al_2O_3	13.94	15.22	14.89	14.99	16.25	14.8
Fe_2O_3	13.15	10.85	11.63	11.29	9.82	2.78
FeO						8.34
MnO	0.20	0.14	0.20	0.19	0.16	0.25
MgO	7.36	10.11	7.93	7.34	6.60	6.62
CaO	11.27	10.41	11.07	10.94	10.26	9.32
Na_2O	2.06	1.53	2.30	2.82	2.32	3.11
K_2O	0.19	0.16	0.31	0.33	0.40	0.53
P_2O_5	0.14	0.10	0.12	0.17	0.12	0.21
Nb	5.8	4.1	4.7	3.3	2.3	1.8
Zr	91.5	64.4	78.7	110.1	58.4	93
Y	29.2	22.6	25.8	35.3	23.3	32.1
Sr	155.4	128.3	194.8	284	278.5	217.7
Rb	2.95	1.6	5.1	4.7	8.1	8
Th	1.0	0.1	0.7	0.9	0.8	1
Ga	19.5	17.3	17.4	17.7	17.9	18.7
Zn	82	62.5	70.3	79.5	69.7	75
Ni	79.9	134.8	98.9	63.5	31.6	42.7
Sc	37.4	36.2	36.4	35.0	38.7	33.3
V	321.6	283	292.3	309.9	327.3	307.8
Cr	145.4	272.2	201.7	162.4	102.9	116.1
Co	51.6	55.4	54.0	47.2	46.1	45.9
Cu	106.5		77.4	77.1		
Ba	53.3	25.1	47.4	43.5	166.3	48.4
La	9.2	4.3	5.9	5.6	6.0	4.7
Ce	16.8	12	12.5	13.5	10.2	10.8
Nd	11.9	9.4	10.1	12.1	10.2	10.1

Analytical data from: Ridgeway and Coulson (1987), Mahoney et al. (1993), Tejada et al. (1996), Neal et al. (1997); unpublished data from: C.R. Neal, J. Mahoney, T. Babbs and A.D. Saunders.

provinces: the islands of Malaita and Ulawa (within the *Pacific Province*), the islands of Makira (San Cristobal), the bulk of Guadalcanal, the Florida Islands, Santa Isabel, and the bulk of Choiseul, (within the *Central Province*), the islands of west Guadalcanal, Savo, the Russell Islands, the New Georgia Group and the Shortland Islands (within the *Volcanic Province*), and the atoll islands of Rennell, Bellona, Sikaiana and Ontong Java (within the *Atoll Province*).

It is timely to revise Coleman's model in the light of new data produced since the late 1970's including the work of the present authors (since 1992). The new terrain model is based on the following criteria: (1) the lithological, geochemical, isotopic, and geochronological characteristics of the respective basement sequences; and (2) relative development (or lack) of subsequent arcs. The oldest basement within the oldest terrains are Cretaceous plateau and ridge basalts with or without related ultramafic complexes. This Cretaceous basaltic basement forms the 'keel' to the Solomon terrain collage (Table 1). Subsequent arc-related terrains have either collided with or extruded/intruded through the Cretaceous basaltic basements. Arc development within the Solomon Islands occurred during two main stages (Tables 2 and 3; Kroenke, 1984; Coulson and Vedder, 1986; Petterson et al., 1997): Eocene–Early Miocene times (here termed *stage 1 arc*); and from Late Miocene to the present day (here termed *stage 2 arc*).

Table 2
Tectonic–lithological–geochemical subdivisions of the Solomon Islands

Lithological units: basement and cover sequences	Age	Islands	Tectonism–magmatism and sedimentation	References
Ontong Java Plateau basement sequence with pelagic sediment cover. Alkalic basalts interbedded with and alnoites intruded into cover sequence. No arc development	OJP basalts 122 Ma, (Malaita), 122 and 90 Ma (Isabel). Cretaceous–Pliocene pelagic sediments. Alkalic basalts (44 Ma), alnoites (34 Ma)	Santa Isabel, north of Kaipito–Korighole Fault (KKF). Malaita, Ulawa	Formed by accretion of Ontong Java Plateau basalts erupted either at a ridge-centered or off-ridge plume head-fissure system. Subsequent deep-sea sedimentation, seamount alkalic volcanism and alnoitic plutonism.	Hughes and Turner (1976, 1977), Davis (1977), Nixon et al. (1980), Danitofea (1981), Hawkins and Barron (1991), Mahoney et al. (1993), Tejada et al. (1996), Neal, Mahoney, Duncan, Babbs and Saunders (pers. commun., 1998)
OJP-like basalt and interbedded MORB basement with pelagic sediment interbeds. Post-basement pelagic sediment cover sequence now eroded.	Preliminary Ar–Ar ages suggest an age range between >90 Ma and c. 30 Ma.	Makira	Formed by accreting both OJP-like plume-related basalts and N-MORB ridge-related basalts.	Solomon Islands Geological Survey (SIGS) (unpubl. work, 1997). Babbs and Saunders (pers. commun., 1997), Duncan, Mahoney, and Neal (pers. commun., 1998)
N-MORB basaltic basement ± ultrabasic intrusive rocks.	Probable Cretaceous, e.g. 92 ± 20 Ma, (Mbirao Volcanics of Guadalcanal).	Guadalcanal, Choiseul	Mid-ocean-ridge-centered volcanism/plutonism	Babbs, Saunders, Mahoney, and Neal (pers. commun., 1996), Hackman (1980), Ridgeway and Coulson (1987)
Stage 1 arc sequence. Ultramafic, N-MORB, BAB, and IAB ± alkaline basalts. More evolved calc-alkaline andesitic–rhyolitic volcanic/plutonic rocks. Volcaniclastic-dominated sediments plus intra-arc carbonates.	Paleocene/Eocene–Early Miocene. 62 Ma–46 Ma (Isabel). Floridas basement sequence (45 Ma–37 Ma). Poha Diorite (Guadalcanal) 24.4 ± 0.3 Ma.	Forms basement of Shortlands, Santa Isabel south of the KKF, and Floridas. Guadalcanal, Choiseul	Southwards-directed subduction of Pacific plate beneath Solomon Block at North Solomons/Vitiaz Trench. Arc-related volcanism and sedimentation. Uplift of frontal arc.	Neef and Plimer (1979), Hackman (1980), Turner and Ridgeway (1982), Kroenke (1984), Pound (1986), Coulson and Vedder (1986) Ridgeway and Coulson (1987), Tejada et al. (1996),
Stage 2 arc sequence. Typical arc calc-alkaline basalt–rhyolite sequence. Unusual sodic basalts-dacites. Alkaline/shoshonitic basalts-trachytes. High-Mg basalts-andesites and picrites. Micro-granites present on Makira. Volcaniclastic-dominated sediments.	Later Miocene–Recent. 6.4 ± 1.9 Ma (Gallego Volcanics of W. Guadalcanal). 4.5 Ma–1.5 Ma (Koloula Diorite Complex, S. Guadalcanal). 2.3 ± 1 Ma, (New Georgia).	Shortlands, Choiseul, New Georgia Group, Russells, Savo, ?Floridas, Guadalcanal, Makira	Northwards subduction of Australian plate beneath Solomon block with contemporary southwards-directed (Vitiaz) subduction occurring locally. Arc-related magmatism and sedimentation. Opening and subsequent subduction of Woodlark basin. Shortening of S. OJP. Regional uplift.	Hackman (1980), Chivas (1981), Turner and Ridgeway (1982), Dunkley (1983), Kroenke (1984), Dunkley (1986), Pound (1986), Coulson and Vedder (1986), Ridgeway and Coulson (1987), SIGS (unpubl. data, 1997), Petterson and Wilson (unpubl. data, 1997).

Table 3
Terrain-time diagram for the Solomon terrain collage

Terrain-time diagram	South Solomon MORB Terrain (Guadalcanal and Choiseul)	Ontong Java Plateau Terrain (Malaita, North Isabel and Ulawa)	Makira Terrain (Makira)	Central Solomon Terrain (Floridas, South Isabel and Shortlands)	New Georgia Terrain (New Georgia and Russell Islands, Savo)
Cretaceous	N-MORB basalt + ultramafic magmatism	Formation of Ontong Java Plateau. Deep-sea pelagic sedimentation.	Contemporaneous plume and MORB basaltic magmatism + pelagic sedimentation.		
Paleocene/ Eocene to Early Miocene	Stage 1 arc volcanism and related sedimentation	Pelagic + turbiditic sedimentation. Alk. basalt + alnoitic magmatism.	Plume + MORB magmatism + pelagic sedimentation.	Basement formed by stage 1 arc magmatism.	
Late Miocene to Recent	Stage 2 arc volcanism, plutonism and related sedimentation	Pelagic + shallow water sedimentation. Accretion to Solomon arc.	Development of stage 2 arc on plume + MORB basement.	Variable development of stage 2 arc.	Formation of New Georgia Terrain by stage 2 arc magmatism.

3.1. Geochemical subdivision of basement terrains

One of the clearest ways of illustrating tectonic distinctions between key Solomon Island terrains is by plotting a simple Nb–Zr scatter plot (Fig. 4) of basement basalts from three key Solomon terrains (the terrains are formally defined below). Fig. 4 subdivides basement basalts from the islands of Malaita, Ulawa, Santa Isabel, Makira, Guadalcanal and Choiseul into two distinct geochemical fields. Basalts from Malaita, Ulawa, and northern Santa Isabel have identical compositions to Ontong Java Plateau (OJP) basalts and plot alongside OJP basalt samples derived from the Ocean Drilling Project. Basalts from Guadalcanal and Choiseul have higher Zr/Nb ratios and have compositions more akin to Mid Ocean Ridge Basalt (MORB). Makiran basalts are of a hybrid nature with both plateau and MORB lavas being mutually interbedded. Fig. 5 is a MORB-normalised multi-element plot of average basalt compositions (Table 1) from the basements of Choiseul, Guadalcanal, Makira, and Malaita, which illustrates the more enriched nature of the Malaita (OJP) and Makira Plateau basalts relative to the Makira MORB, Choiseul, and Guadalcanal basalts, especially with respect to the more incompatible immobile elements such as Nb, La, and Ce. Fig. 4 in particular provides a simple geochemical basis on which a first sub-division of the basaltic basement of Solomon Islands can be made; this sub-division becomes more convincing when the full range of geological, geochronological, and isotopic data are considered.

3.2. Cretaceous basement sequences

The most fundamental subdivision of Solomon Islands is with respect to the oldest (Cretaceous) known basement exposed on the islands of Choiseul, Santa Isabel, Malaita, Ulawa, Makira, and Guadalcanal (Fig. 2, Table 1). The Cretaceous basement is divisible into three distinct terrains: a northern 'Ontong Java Plateau Terrain' (OJPT), a southern 'South Solomon MORB Terrain' (SSMT), and an eastern 'Makira Terrain'. The OJPT comprises Santa Isabel north of the Kaipito–Korighole Fault, or KKF (the KKF is an intra-island terrane boundary, dividing the island of Santa Isabel into two terrains as shown in Fig. 2), Malaita, and Ulawa. The SSMT comprises the basements of Guadalcanal and Choiseul. The geochemical distinctions between these terrains have been briefly discussed above (Figs. 4 and 5) and reflect their respective origins as products of massive plume-related melting (in the case of the OJPT) and lower-degree tholeiitic partial melts at a conventional ocean ridge (in the case of the SSMT). The Makira Terrain is

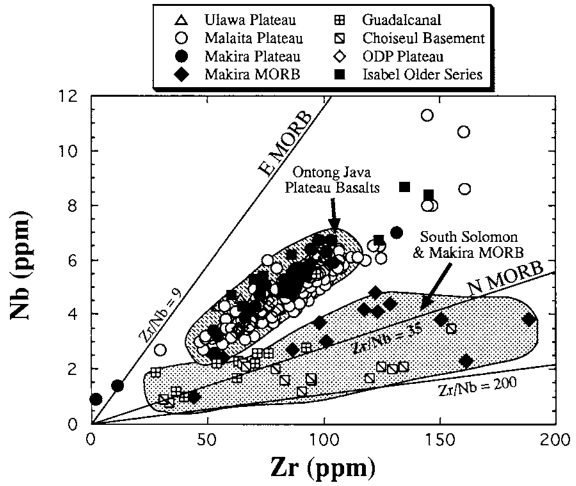

Fig. 4. Nb–Zr variation diagram for basaltic basement sequences from Ulawa, Malaita, Makira, Guadalcanal, Choiseul, Santa Isabel, and ODP borehole samples from the OJP. The basement of the islands of Malaita, northern Santa Isabel and Ulawa plot with samples derived from the OJP proper (ODP samples) and together form the Ontong Java Plateau field with Zr/Nb ratios transitional between 'E'- and 'N'-type MORB. The islands of Guadalcanal and Choiseul define a more MORB-like geochemical field with Zr/Nb ratios $\geq$20. Samples from Makira have affinities with both groups: approximately two thirds of analysed Makira samples have a plume/plateau-like chemistry whilst the remaining one third have a MORB-like chemistry. Makira-MORB and plateau basalts are mutually interbedded.

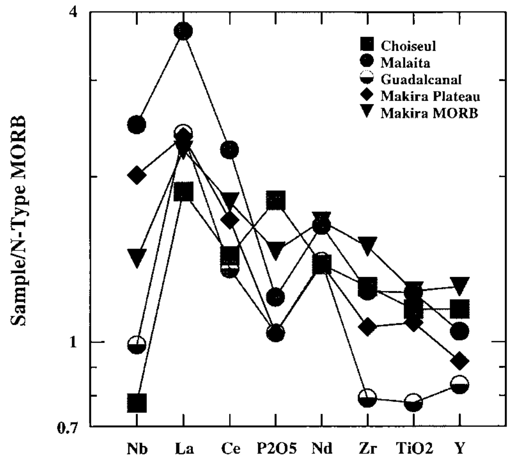

Fig. 5. N-MORB normalised (after Sun and McDonough, 1989) multi-immobile element patterns for average compositions of basement basalts from Choiseul, Malaita, Guadalcanal, and Makira (data given in Table 1). Note the relative enrichment of the Malaita (OJP) Plateau basalts in the more incompatible elements such as Nb, La, and Ce. The Makira Plateau basalts have identical trace element patterns to the OJP, but are less enriched. The more MORB-like basalts of Guadalcanal, Choiseul, and Makira tend to have flatter multi-element patterns indicating their closer affinity to N-MORB. REE data of Choiseul basement basalts show LREE depletion typical of N-MORB (Ridgeway and Coulson, 1987).

more complex in the sense that basalts of Cretaceous–Oligocene age display a hybrid chemistry of both plume/plateau and MORB-like affinities.

3.3. Ontong Java Plateau Terrain (OJPT): OJP basement with no subsequent arc development

Geochemical analysis of basalts from Ocean Drilling Project sites 803 and 807 and from outcrops from on northern Santa Isabel, Malaita and Ulawa, plot within a tightly bounded field in Fig. 4 with an average Zr/Nb ratio of c. 17 (ranging between 13 and 20). The Nb–Zr plot illustrates one of the key characteristics of plateau basalts: they are transitional in composition between tholeiitic N-MORB (with Zr/Nb ratios of c. 35) and the more enriched E-MORB (with Zr/Nb ratios of c. 9). Age data from the OJPT basalts (Petterson et al., 1997; Neal et al., 1997) demonstrate a bimodality in ages (122 Ma and 90 Ma), identical to that of the OJP proper (Mahoney et al., 1993; Petterson, 1995; Tejada et al., 1996; Neal et al., 1997; Petterson et al., 1997). The similarity in geochemical composition is borne out by mapping evidence. The basement of all of the OJPT islands comprises an exceptionally thick sequence of basalt lavas and sills with a smaller volume of coarser-grained basic plutonic rocks. Recent work suggests that as much as 3–4 km of basalts are exposed on Malaita (Petterson et al., 1997). The lack of inter-sheet sediment indicates high effusion rates. These basement stratigraphies all reflect anomalously thick ocean crust more typical of large igneous provinces (LIP's) than 'normal' ocean crust (Coffin and Eldholm, 1994). The OJPT is interpreted as having formed as an integral part of the OJP.

Post-basement sequences on Malaita, Santa Isabel (north of the KKF) and Ulawa (Danitofea, 1981) record a deep pelagic sedimentary history punctuated only by relatively minor volumes of alkalic basalt and alnoitic magmatic activity during the Eocene–Oligocene (Table 1; Tejada et al., 1996; Petterson et al., 1997; see below for details of Malaitan geology). These islands have not been affected by any subsequent arc activity.

3.4. South Solomon MORB Terrain (SSMT): Cretaceous basement and subsequent arc development

The islands of Choiseul and Guadalcanal comprise the SSMT. Fig. 4 illustrates the geochemical distinction between the SSMT and OJPT in Nb–Zr space. Basalt samples from Choiseul and Guadalcanal plot below the OJP field having significantly higher Zr/Nb ratios, more typical of N-MORB. SSMT basalts are also more depleted in light rare earth elements (LREE) with typical LREE-depleted N-MORB rare earth element patterns (Fig. 5; Ridgeway and Coulson, 1987 — REE data from the Choiseul basement).

Hackman (1980) and Ridgeway and Coulson (1987) describe the lithological character of basement sequences from Guadalcanal and Choiseul, respectively. As a general observation the basement lithology of SSMT islands (in particular Guadalcanal) is somewhat more varied than the basement of the OJPT, comprising basalt lavas, pelagic limestones ± cherts, basaltic sills and dykes, gabbros and ultrabasic bodies, and basalt breccias. Perhaps this more varied lithological sequence reflects a more 'normal' ocean floor sequence. The SSMT formed at a 'normal' mid-ocean ridge at some great distance from the eruptive centres of the OJP. The basement Mbirao Volcanics of Guadalcanal have yielded a poorly constrained K–Ar whole-rock age of 92 ± 20 Ma (Hackman, 1980). Unfortunately the basement sequence of Choiseul has not yet yielded a definitive radiometric age, but stratigraphic and structural evidence suggest a probable Cretaceous age (Ridgeway and Coulson, 1987).

Both Choiseul and Guadalcanal contain stage 1 and 2 arc sequences which have been extruded onto and intruded into Cretaceous MORB basement. The stage 1 (Vitiaz) arc is represented on Guadalcanal by the Oligocene–Miocene Suta Volcanics and their volcaniclastic derivatives and the 24 ± 0.3 Ma Poha Diorite, (Hackman, 1980; Chivas, 1981) and on Choiseul by crystal- and lithic-rich turbidites (the Oligocene–Miocene Mole Formation (Ridgeway and Coulson, 1987). The stage 2 arc is represented on Guadalcanal by the Late Miocene–Pleistocene Gallego Volcanics (one K–Ar age determination of 6.4 ± 1.9 Ma: Hackman, 1980) as well as the similarly aged Gold Ridge Volcanics of central Guadalcanal, and the Plio–Pleistocene Koloula Diorite Complex (Chivas, 1981). The stage 2 arc is represented on Choiseul by the Miocene–Pliocene Maetambe and Komboro Volcanics. Volcanism during stage 2 arc times on Guadalacanal was from northwards-directed subduction below the SSTS, whereas the Choiseul stage 2 arc volcanics owe their origin to southwards-directed subduction from a locally re-activated Vitiaz trench system (see below).

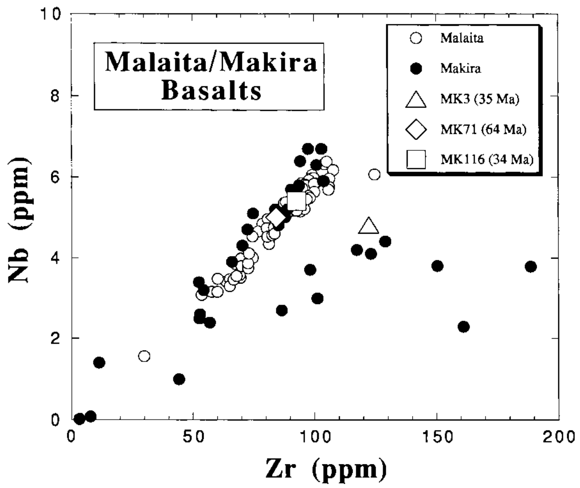

Fig. 6. Nb–Zr variation diagram for basaltic samples from Malaita and Makira. 'Makira Plateau' samples have Zr/Nb ratios of circa 17 and plot with the Malaita samples within the OJP field (Fig. 3), while the 'Makira MORB' samples have Zr/Nb ratios of >25. The samples MK3, MK71, and MK116 are samples from Makira which have yielded Ar–Ar ages.

3.5. Makira Terrain: a composite plateau basalt and MORB Cretaceous–Oligocene basement with subsequent stage 2 arc development, uplift, and deep dissection

Makira is a special case within the Solomon block. Figs. 4 and 6 show that in terms of Nb–Zr composition about two-thirds of the Makiran samples analysed to date plot within the OJP field (here termed Makira Plateau samples), but, intriguingly, about one-third of the basalt samples have Zr/Nb ratios transitional between the more MORB-like Choiseul samples and the OJP field (here termed the Makira MORB samples).

Fig. 6 shows the variation in Nb–Zr ratios particularly well with the Makira Plateau samples having Zr/Nb ratios of c. 17, whilst the Makira MORB samples have Zr/Nb ratios of c. 25 or higher. We interpret the geochemistry of Makira MORB samples as indicating a probable 'normal' mid-ocean ridge (MOR) origin, with possible plume contamination in some cases. This interpretation is also provisionally supported by isotopic data (J.J. Mahoney, unpubl. data). Field relations confirm that Makiran MORB and Plateau basalts are stratigraphically interleaved. This penecontemporaneity of Makira MORB and Makira Plateau is borne out by Fig. 6 which shows that two samples with similar ages (35 Ma and 34 Ma, respectively) plot in different fields of Nb–Zr space. Interpretation of data from Makira is still at an early stage and it would be premature to make any firm statements in this paper. However, the implication of these data are that Makira was a depocentre for basalts from two geochemically distinct sources: an OJP-like (and we stress 'OJP-like' in terms of composition; we are not making a genetic connection) plume-dominated source, and an N-MORB dominated source. Many basalt sequences on Makira are interbedded with metres to tens of metres of pelagic chert and limestone indicating periods of relative volcanic quiescence. Other basalt sequences (perhaps the bulk) contain little or no inter-sheet non-basaltic sediment, indicating rapid effusion rates.

Recent Ar–Ar plateau age determinations have yielded ages of 63.0 ± 0.5 Ma and 33.9 ± 0.7 Ma for two Makira Plateau basalt samples, and 35.1 ± 1.1 Ma for one Makira MORB sample, and as this paper goes to press older ages of the order of >90 Ma have been determined (R.A. Duncan, unpubl. data), indicating Cretaceous–Oligocene basement formation. Interestingly, this overlaps with both the second stage of OJP igneous activity (at c. 90 Ma; Mahoney et al., 1993; Neal et al., 1997) and the Eocene–Oligocene alkaline basalt and alnoite intrusive activity within the OJP (Davis, 1977; Neal and Davidson, 1989).

Makira is a deeply eroded piece of crust. Evidence to support this statement includes the following. (1) The basement sequence is lithologically more varied than that of Malaita with basaltic breccias, gabbros and gabbro pegmatites being common. A few of the samples analysed are very primitive high-Mg or high-Ca basalts which are probably part-cumulate in origin. (2) The basement sequence is generally more highly veined and altered than in Malaita with localised shear zones in which the rocks are altered to greenschist. This may indicate that deeper crustal levels are exposed and/or that Makira experienced pervasive ocean floor hydrothermal alteration. (3) Makira has little or no deep-sea pelagic cover sequence preserved. There are intra-basement sediments indicating a deep-sea pelagic eruptive environment. (4) There is abundant evidence for the development of a probable stage 2 arc sequence on Makira. Microgranite dykes and intermediate–acid reworked tuffs are common lithologies within the 'float' geology of many river systems, although these sequences do not commonly crop out. Only small-scale outliers of probable stage 2 arc rocks remain; there are no volcanic structures preserved.

This situation contrasts strongly with western Guadalcanal where the stage 2 arc sequences *and* volcanic structures are very well preserved (e.g. the Gallego Volcanics, Hackman, 1980; Petterson and Biliki, 1995). The situation in Makira is more akin to that of south Guadalcanal where the deep-level plutonic roots of the stage 2 arc (the 4.5 Ma–1.5 Ma Koloula Plutonic Complex; Chivas, 1981) are exposed. Hackman (1980) estimated that south Guadalcanal has undergone >2 km of uplift since the Late Pliocene. This recent uplift event is probably a result of the proximal forearc position of Guadalcanal and Makira with respect to the SSTS. The structure of Makira is dominated by block faulting, fault block rotation, and open folding. Most recently, Makira has been affected by the oblique collision between the Pacific and Australian plates which has produced significant left-lateral strike-slip tectonics, pull-apart basins, and a general transpressive tectonic regime. Interpreted fault patterns on Makira are not unlike those described by Auzende et al. (1994) which are readily explained by transpressive, sinistral, strike-slip tectonics.

3.6. Central Solomon Terrain (CST): stage 1 (Vitiaz) arc basement; the Florida Islands, south Santa Isabel, and Shortland Islands

The Florida Islands, Santa Isabel south of the Kaipito–Korighole Fault, and the Shortland Islands are here termed the 'Central Solomon Terrain' (CST) which in our classification system encompasses stage 1 arc-dominated basement, ± stage 2 arc. Basement sequences from the Shortlands, south Santa Isabel and the Floridas, are arc-like and ophiolitic in character (Neef, 1979; Neef and Plimer, 1979; Plimer and Neef, 1980; Ridgeway and Coulson, 1987; Tejada et al., 1996). The basement sequences are predominantly basic to ultrabasic with N-MORB, island arc basalt, back-arc basalt, and alkalic basalt compositions (the latter on Shortlands). All islands also contain more evolved andesitic and dacitic calc-alkaline arc sequences.

Radiometric dating and stratigraphical evidence indicate that the age of exposed crust within the CST is predominantly Eocene to Early Miocene, although Tejada et al. (1996) recently determined a small number of Paleocene Ar–Ar ages from back-arc basalts on south Santa Isabel. There are no age data available for the Shortlands but Neef and Plimer (1979) quoted K–Ar amphibole ages of between 44.7 ± 2.1 Ma and 35.2 ± 1.4 Ma for basement basalts and ultrabasic rocks from the Florida Islands (Table 2). An Eocene K–Ar radiometric age of 44 ± 18 Ma for the Choiseul Schists (Pound, 1986; Ridgeway and Coulson, 1987) is interpreted by Kroenke (1984) as indicating uplift and metamorphism within a proximal frontal forearc position associated with the initiation of south-directed Vitiaz (north Solomon) arc subduction.

Stratigraphic evidence for the Suta Volcanics of Guadalcanal suggests a probable Oligocene–Early Miocene age (Hackman, 1980): they are intruded by the Poha Diorite which is dated at 24.4 ± 0.3 Ma (Chivas, 1981). The Mole Formation of Choiseul contains arc-derived volcaniclastic material which is interpreted as Oligocene–Miocene in age by Ridgeway and Coulson (1987).

The bulk of the age data (whether radiometric or stratigraphic) suggest that there was a major arc crustal genesis stage, during Eocene–Early Miocene times, which formed the bulk of the basement of the CST and added supracrustal sequences to Guadalcanal and Choiseul. Geochemical data suggest that magmatism occurred within arc and back-arc to intra-arc tectonic environments. This stage 1 (Vitiaz) arc was related to south-directed subduction of the Pacific plate beneath the Solomon block (e.g. Tables 2 and 3; Kroenke, 1984).

3.7. New Georgia Terrain (NGT): stage 2 arc-dominated sequences; Savo, Russell Islands, Kavachi, New Georgia Group, and submarine volcanism south of New Georgia

The New Georgia Terrain (NGT) defines the crustal area whose sialic basement formed during the present stage of arc growth within the Solomon Islands. The NGT is thus defined as 'stage 2 arc with unknown older basement' or 'stage 2 arc-dominated crust'. This second stage of arc growth has also led to supracrustal additions to older terrains, in particular on Makira, Guadalcanal, and Choiseul (Tables 2 and 3). The NGT includes the islands of the New Georgia Group, the area of arc-related submarine volcanism south of New Georgia (e.g. the Ghizo ridge etc.), the Russell Islands, Kavachi, and Savo (Fig. 2). The NGT probably also includes the southern and central arcuate submarine volcanoes recently discovered to the east of Makira (Kroenke, 1995).

The composition and character of arc volcanism within the Woodlark basin is very complex with intermediate–acid, calc-alkaline, arc-related material forming major volcanic edifices such as the Ghizo ridge and Coleman seamount on top of an oceanic, tholeiitic to high-Na–Ti basaltic basement (Crook and Taylor, 1994). A wide spectrum of igneous compositions from high-Mg picrites to calc-alkaline basalts, andesites and dacites is exposed within the volcanic sequences of the New Georgia Group (Ramsay et al., 1984; Dunkley, 1986) with a spectrum of compositions. Exposures on Savo reveal a basement of arc-related ultrabasic to basic plutonic rocks overlain by a complex sequence dominated by dacitic block and ash flows with occasional interbedded andesite and basalt flows (Petterson et al., 1998; and unpublished data). Volcanic sequences similar to Savo are exposed in western Guadalcanal (Hackman, 1980). Makira contains microgranite dykes and south Guadalcanal contains gabbro-diorite to granite plutonic sequences within their respective more highly dissected topographies (Chivas, 1981; Petterson et al., unpublished data). Many sequences within the stage 2 Solomon arc NGT also contain epiclastic sequences typical of active arc environments (Hackman, 1980).

Age data are sparse for the NGT. Only three radiometric ages are published: a K–Ar age of 6.4 ± 1.9 Ma for the Gallego Volcanics of western Guadalcanal (Hackman, 1980); a range in K–Ar ages between 4.5 and 1.5 Ma for the Koloula plutonic complex of south Guadalcanal (Chivas, 1981); and a K–Ar 2.3 Ma age for New Georgia (Dunkley, 1986). On many islands the oldest exposed volcanic rocks are Pliocene or younger (Dunkley, 1986). Yan and Kroenke (1993) suggested that subduction began along the SSTS at around 12 Ma. There is no definite evidence within the Solomon Islands that arc volcanism began earlier than the latest Miocene (c. 8 Ma). However the paucity of age data make it difficult to draw conclusions regarding the initiation of the stage 2 arc within the Solomon Islands. What is apparent is that the second stage of arc crustal growth was related to a reversal in subduction polarity: subduction switched from being south-directed at the Vitiaz trench to being north-directed at the SSTS, as the Australian plate began to subduct beneath the Solomon block.

4. The contrasting geological and geochemical evolution of Guadalcanal and Malaita

Malaita and Guadalcanal represent two extremes of geological and geochemical evolution within the Solomon terrain collage. Malaita essentially formed during one intra-oceanic, basaltic, large igneous province event and was accreted to the Solomon terrain collage with only relatively minor additions to its early basement. Guadalcanal initially formed within an intra-oceanic ridge environment, but was subsequently affected by two arc stages of crustal growth.

4.1. Geology of Malaita

Details of the geology of Malaita are published in Petterson (1995), Mahoa and Petterson (1995) and Petterson et al. (1997). Fig. 7 is a simplified geological map of northern and central Malaita. The basaltic basement (Malaita Volcanic Group) of Malaita is exposed within the cores of a number of asymmetrical periclinal anticlines which verge to the northeast and have shallow dipping western limbs and steeply dipping to overturned eastern limbs. The Malaita Volcanic Group is dated at 120–125 Ma and comprises a monotonous sequence of pillowed and non-pillowed tholeiitic basalt sheets with occasional gabbroic intrusive bodies. Intra-sheet sediment is remarkable by its general absence indicating a very high effusion rate for the basalt sheets. Fig. 8 illustrates the geochemical composition of the Malaita Volcanic Group which is transitional between N-MORB and OIB and is identical to the OJP. The Malaita Volcanic Group is overlain by a Cretaceous–Pliocene sedimentary cover sequence dominated by deep-sea pelagic cherts and limestones, with arc-related turbidites becoming interbedded with the limestones from the Eocene onwards. There were brief periods of alkaline basaltic volcanism and alnoitic intrusive activity during the Eocene and Oligocene respectively. The youngest Pliocene–Recent shallow water clastic and reef limestone formations unconformably overlie the Malaita Volcanic Group and the pelagic sedimentary cover sequence. This unconformity was produced by the uplift and transpressive deformation related to the obduction of the OJP against the Solomon arc, mainly between 4 and 2 Ma (Petterson, 1995; Petterson et al., 1997).

Thus Malaita and the OJPT in general were formed during a plateau accretion basaltic crustal genesis event at about 122 Ma. Unlike Santa Isabel, Malaita does not contain the younger 90 Ma OJP lavas. The OJPT terrain drifted passively at ocean depths of c. 2 km or deeper slowly accumulating a pelagic sediment pile 1–2 km thick. As the edge of the OJP passed over a hot spot during Eocene–Oligocene times alkaline basalts and alnoites were extruded or intruded through the OJP (Nixon et al., 1980; Nixon and Neal, 1987; Neal and Davidson, 1989). Finally as the OJP encountered the Solomon arc, parts of it were obducted to form the OJPT. Thus Malaita has undergone little whole-crust geochemical evolution during the 122 Ma of its existence and still remains a basaltic crustal domain (Figs. 7 and 8; Petterson et al., 1997; Neal et al., 1997).

4.2. Geology of Guadalcanal

The geology of Guadalcanal has been described by Hackman (1980) and Coulson and Vedder (1986). The basement is exposed in the south and west of Guadalcanal and comprises two main lithological types: the basalt-dominated Mbirao Group and the Guadalcanal Ultrabasics (Fig. 9A). The Mbi-

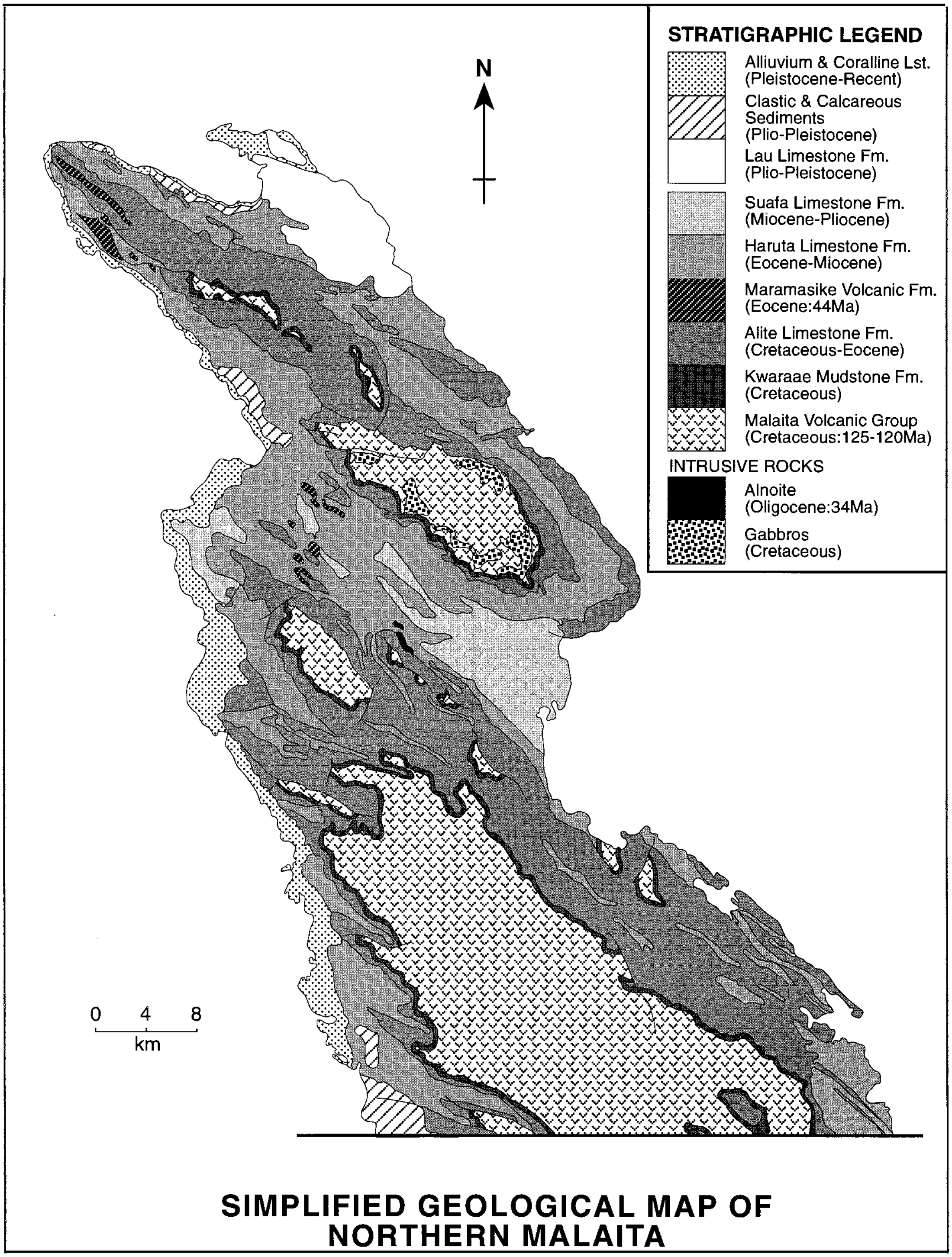

Fig. 7. Simplified geological map of northern and central Malaita. See text for details.

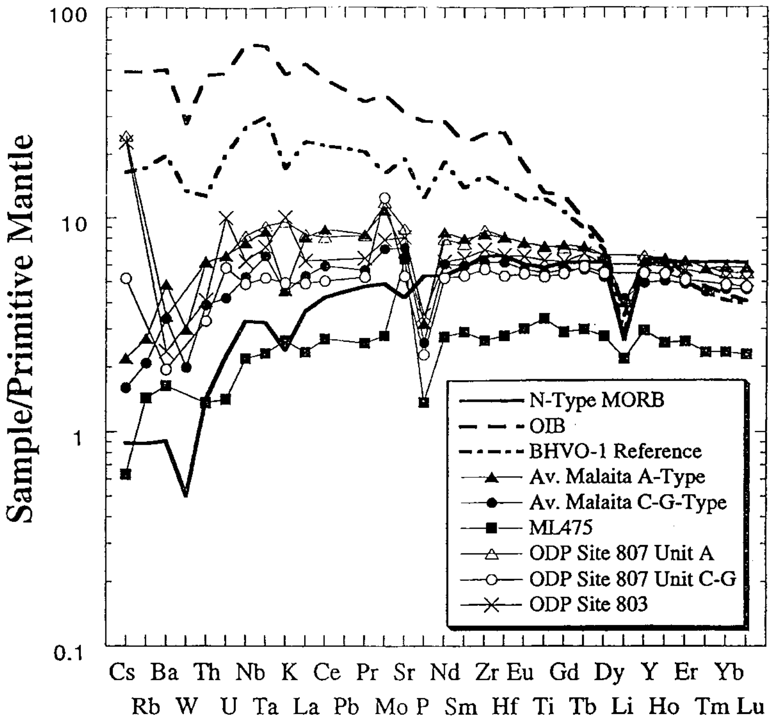

Fig. 8. Multi-element plot (normalised relative to primitive mantle after Sun and McDonough, 1989) of basalts from Malaita (samples labelled *ML*, *Malaita A* and *Malaita C-G*) and samples from the Ocean Drilling project (*ODP*). Also included are the compositions of N-MORB, Ocean Island Basalt (*OIB*) and a *BHVO-1* standard reference sample. Note the identical composition of Malaitan basalts relative to basalts sampled by the ODP. Malaitan samples have greatly extended the database for the OJP by providing a thick (up to 4 km) section through the upper OJP crust: sample ML 475 is the most MgO-rich sample (9.99%) yet obtained from the OJP (Neal et al., 1997).

rao Group is a sequence dominated by basalt lavas and sheets with interbedded cherts and pelagic limestones and intrusive dolerite dykes and sills and larger gabbroic intrusive bodies. A gabbro sample from the Mbirao Group has yielded a K–Ar age of 92 ± 20 Ma (Hackman, 1980). The Guadalcanal Ultrabasics comprise a series of ultramafic bodies which are predominantly harzburgitic in composition with associated anorthosites and a variable sequence of serpentinites.

The post-basement sequence of Guadalcanal is up to 6000 m thick (Fig. 9A and B). The oldest unit within this sequence is the Oligocene–Miocene Suta Volcanics (and related Poha Diorite which has yielded a K–Ar age of 24.4 ± 0.3 Ma, Chivas, 1981) which are a variable sequence of porphyritic basaltic andesites to andesites with associated volcaniclastic material, much of which was redeposited to form thick turbidite units such as the Kavo Greywacke Beds. Contemporary reef limestones are preserved in formations such as the Mbonehe and Mbetilonga limestones. Oligocene–Miocene rocks are exposed in central-southern and west Guadalcanal (Fig. 9B). The Plio–Pleistocene deposits of Guadalcanal are dominated by the Gallego (west Guadalcanal) and Gold Ridge (central Guadalcanal) Volcanics and related reworked epiclastic sediments, such as the Lungga Beds, and Toni Formation. The Gallego and Gold Ridge Volcanics are dominated by basaltic andesitic to dacitic pyroclastic flows and lavas with associated diorite–granitoid intrusions. The epiclastic formations consist of volcanic conglomerates, breccias, sandstones and finer-grained units. The Gallego Volcanics have yielded one K–Ar age of 6.4 ± 1.9 Ma (Hackman, 1980). The Pliocene Mbokokimbo Formation of central-east Guadalcanal comprises a variable sequence of siltstones, mudstones and shales with smaller volumes of sandstones and conglomer-

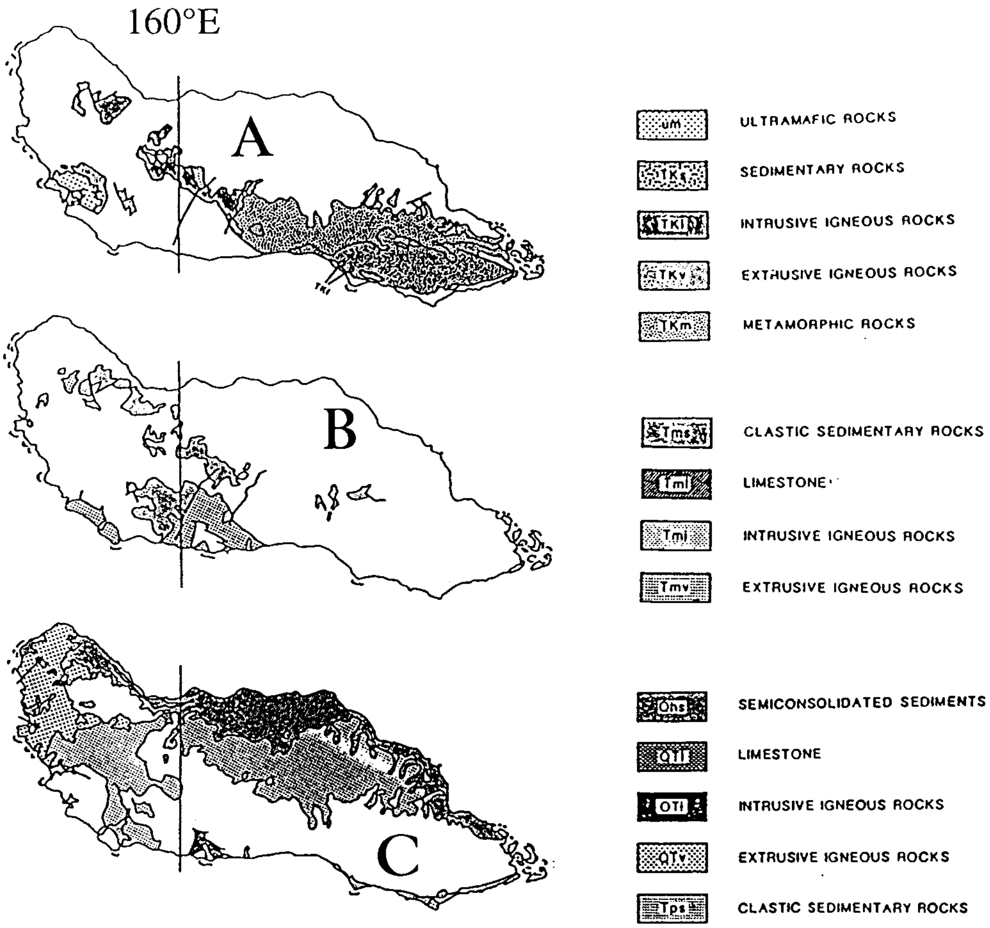

Fig. 9. The geological evolution of Guadalcanal with snapshots of the geology formed during: (A) Cretaceous–Early Tertiary times; (B) Oligocene–Late Miocene times; and (C) Late Miocene–Holocene times. The oldest rocks of Guadalcanal are exposed mainly in the south and comprise Cretaceous basalt and ultrabasic rocks (the Mbirao Group and Guadalcanal Ultrabasics). The Early Tertiary rocks are represented by the porphyritic andesite-basaltic andesites of the Suta Volcanics together with associated plutonic rocks (e.g. the Poha Diorite) and volcaniclastic/epiclastic rock sequences. Early Tertiary–Late Miocene rocks are exposed in central-west Guadalcanal. The Late Miocene–Holocene rock sequences are dominated by intermediate–acid volcanic–plutonic sequences in central-west and south Guadalcanal (e.g. the Gallego Volcanics), fine-grained mud rocks in central-east Guadalcanal (the Mbokokimbo beds) and up to 800 m of raised coralline terraces (the Honiara beds) and thick alluvial plains in north-central Guadalacanal. The vertical line drawn through Guadalcanal is the 160º line of longitude, indicating the north–south direction. Map data from Coulson and Vedder, 1986.

ates. The Mbokokimbo Formation exhibits complex facies relationships and contains both deep-water pelagic foraminiferal and shallow-water varied benthonic fauna (e.g. foraminifera, bivalves, etc.). The multi-intrusive, mineralised, and diorite dominated Koloula Complex crops out in south-central Guadalcanal and has been dated at between 4.5 and 1.5 Ma (Chivas, 1981). Quaternary and Recent sedimentation is dominated by the voluminous alluvial deposits of the Guadalcanal plains of central-north Guadalcanal, and the spectacular raised coralline reefs of the Honiara Beds which rise in a series of raised terraces to 800 m above sea level. Plio–Pleistocene and Recent deposits are exposed mainly in west and central-north Guadalcanal.

Figs. 10 and 11 illustrate the variable compositions of the Guadalcanal basement (Mbirao Volcanics), the second stage arc lavas (Suta Volcanics) and the second stage volcanic and intrusive rocks (Gallego Volcanics and Koloula Complex). These

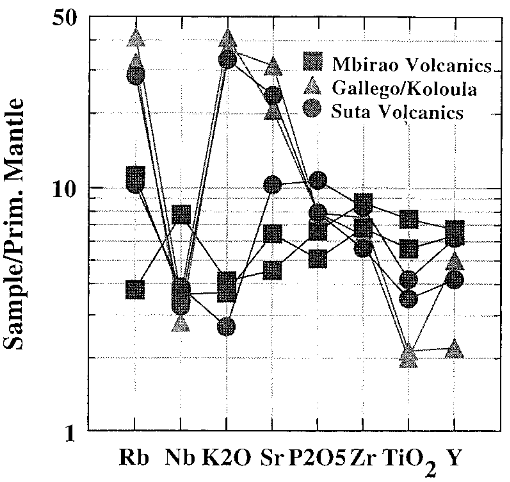

Fig. 10. Primitive normalised (after Sun and McDonough, 1989) multi-element plots for samples from the Guadalcanal basement (Cretaceous Mbirao Volcanics); stage 1 arc (Oligocene–Miocene Suta Volcanics) and stage 2 arc (Miocene–Pliocene Gallego Volcanics and Koloula diorite). Note the relatively flat trace element trends of the basalt-dominated basement and the typical arc signatures of the stage 1 and 2 arc rocks (e.g. relative depletions in Nb TiO_2 and Y and enrichments in Rb, K_2O and Sr). The second stage arc rocks are more silicic and evolved relative to stage 1 arc rocks demonstrating a general evolution towards more evolved compositions with time within the Solomon arc (see also Fig. 11).

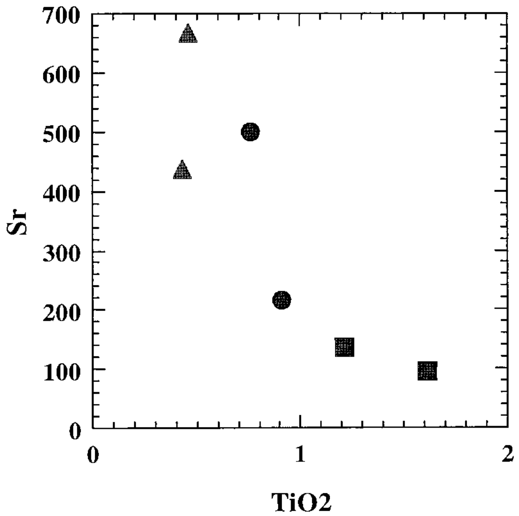

Fig. 11. Sr–TiO_2 scatter plot for Guadalcanal samples from basement (Cretaceous Mbirao Volcanics); stage 1 arc (Oligocene–Miocene Suta Volcanics) and stage 2 arc (Miocene–Pliocene Gallego Volcanics and Koloula Diorite) rocks. There is a temporal evolution towards more evolved silicic compositions within the Solomon arc. Symbols as for Fig. 10.

figures illustrate the progressive evolution of the magmatic chemistry of Guadalcanal with time from an oceanic basalt-dominated basement to highly evolved arc sequences. The most evolved chemistries are associated with the youngest arc magmas following the general arc trend of increasing acidity of arc magmas with time (e.g. Gill, 1981). The variable geochemistry of magmas with time and the complex volcano-sedimentary units present on Guadalcanal contrast markedly with the much more homogeneous basalt and deep-sea dominated geology of Malaita and emphasise the most marked contrast in terrains within the Solomon terrain collage.

5. Conclusions and discussion

5.1. Tectonic development of Solomon Islands since the Cretaceous

Figs. 12–15 and Tables 2 and 3 summarise the key developments in the evolution and accretion of the Solomon terrain collage.

The OJPT and SSMT Cretaceous basement terrains formed within distinctly different intra-oceanic settings, at considerable distance from one another. The OJPT formed as part of the largest-scale ocean plateau building episode in the Pacific, resulting from plume-related igneous activity either within a ridge or off-ridge, intra-oceanic setting. Fig. 13 gives one possible OJP tectonic setting with the OJP plume rising beneath an active axial rift and incorporating material from a number of source regions within the mantle. There is no evidence that the OJP ever formed a subaerial edifice (Saunders et al., 1993; Petterson, 1995; Petterson et al., 1997; Neal et al., 1997). The OJP formed during two major magmatic episodes dated at 122 and 90 Ma (Mahoney et al., 1993; Neal et al., 1997). We envisage the SSMT as forming within a more ‘normal’ ocean ridge setting. The SSMT subsequently formed the tholeiitic root or basement to an island arc. The time period between the formation of the OJPT and SSMT and the initiation of the stage 1 Vitiaz arc (Cretaceous–Eocene) was dominated by passive, deep-sea, pelagic sedimentation.

During the Eocene the Pacific plate began to subduct southwards producing the stage 1 Vitiaz arc

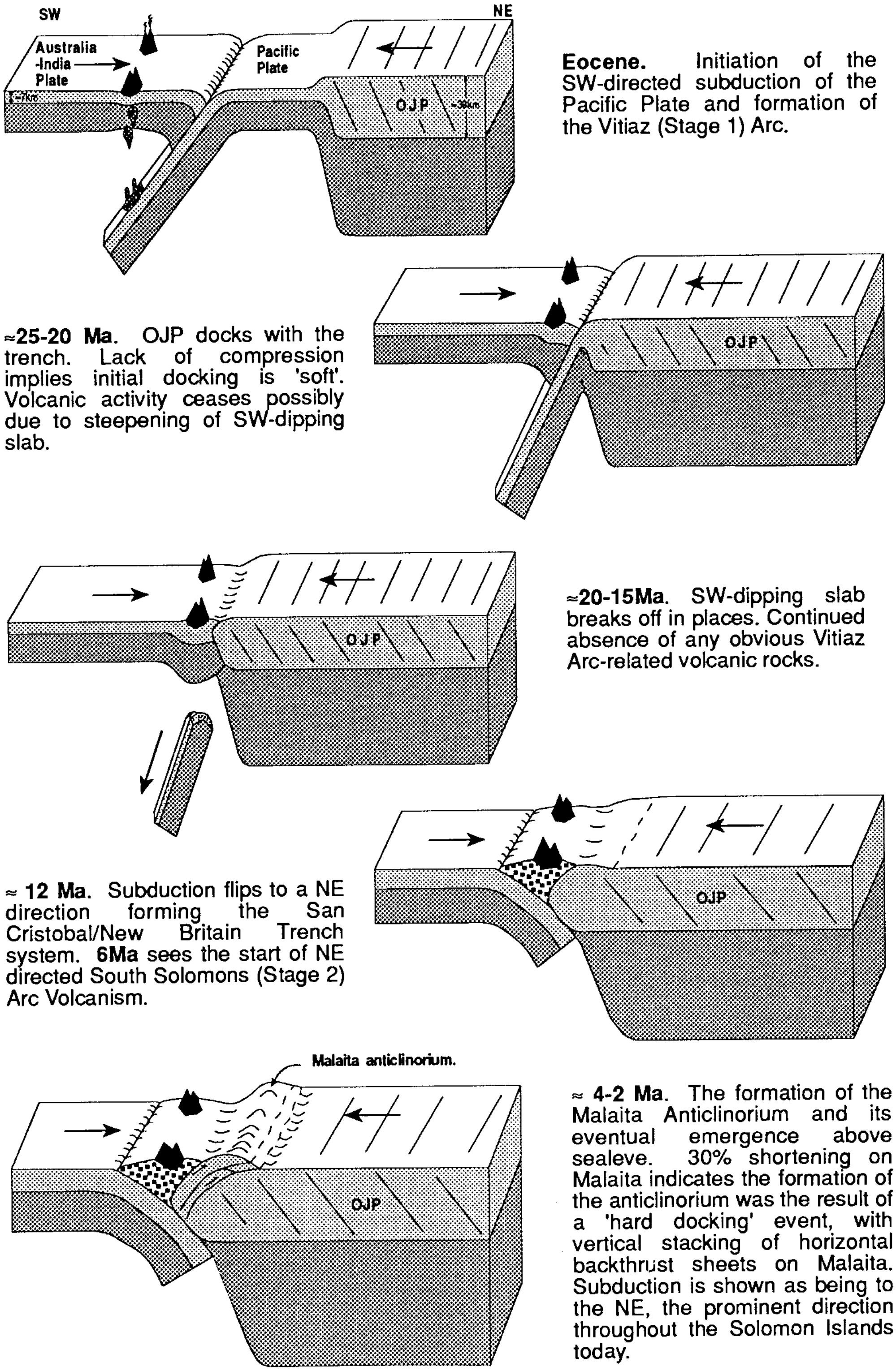

Fig. 12. Tectonic model for the evolution of the Solomon terrane collage from Eocene times. (Reproduced from Babbs, 1997.)

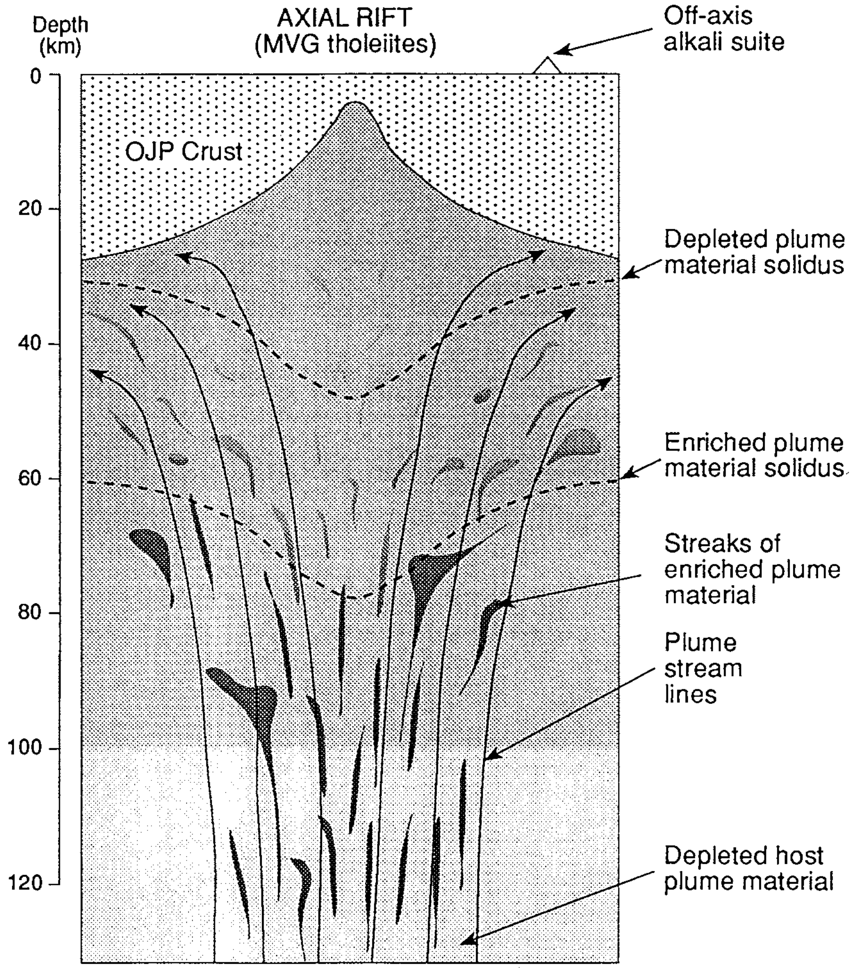

Fig. 13. Possible axial rift/ridge centred model for the Ontong Java Plateau (OJP) plume. In this model a very high-volume, deep-rooted, mantle plume entrains mantle material from a variety of source regions and accretes plateau basalt material to an incipient OJP. Alternatively the OJP plume could have surfaced within an off-ridge setting. Geological evidence suggests that despite the very large scale of the OJP plume it did not produce a plateau structure which rose above sea level, and was probably restricted to deep ocean topographic levels (Saunders et al., 1993; Petterson et al., 1997; Neal et al., 1997). (Reproduced from Babbs, 1997.)

and commencing a major stage of crustal genesis (Fig. 12). This period of arc magmatism began to change the essentially basaltic composition of the SSMT to a more intermediate one, and produced the bulk of the Central Solomon Terrain. Arc magmatism occurred within fore-arc and back-arc environments. Stage 1 Vitiaz arc development was fundamental in creating a block of evolved sialic material within an intra-oceanic environment. The Eocene and Oligocene also saw renewed activity associated with the OJP, as Eocene alkalic basalts were extruded, possibly building submarine seamount structures (Tables 2 and 3; Fig. 7; Petterson et al., 1997) and subsequently ?plume-related alnoite diatremes intruded the OJP. This period of intra-OJP magmatism may have been related to the arching of the OJP as it approached the Vitiaz trench (Coleman and Kroenke, 1981).

The bulk of the Makira terrain formed between the Cretaceous and Oligocene and by the accretion of plume- and normal ocean ridge-basalts. South-directed subduction at the Vitiaz trench ceased dur-

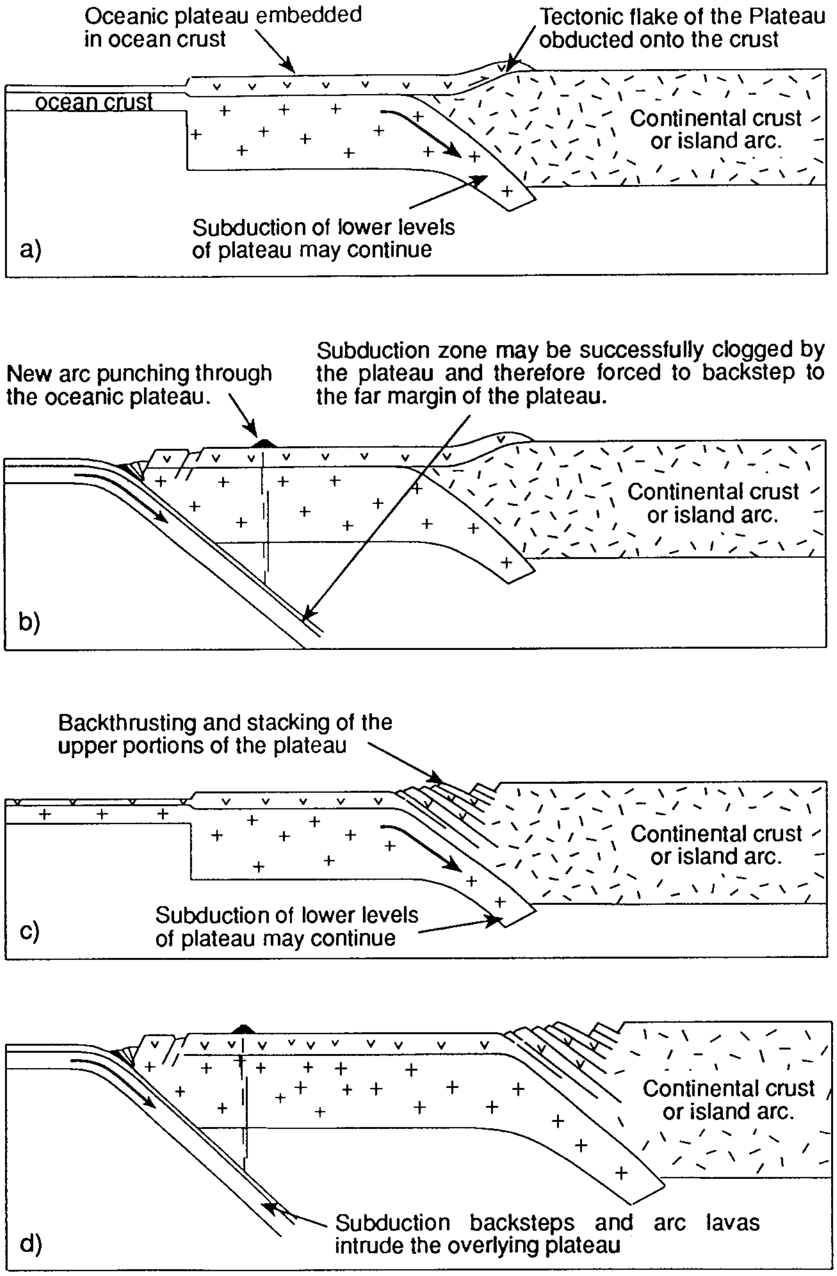

Fig. 14. Models for the obduction of the OJP and ocean plateaus. Petterson et al. (1997) suggested the model depicted in (a) which shows the OJP splitting in two with the upper parts obducting, and the lower parts subducting southwards on and beneath the arc. This model was designed to explain the NE vergence of Malaitan structures and late SW-verging thrust structures imaged within the Malaita anticlinorium (Kroenke, 1995). An alternative model which may more plausibly explain recently acquired geophysical data (e.g. Miura et al., 1996; Mann et al., 1998) is presented in (c). On collision with the Solomon arc the upper portions of the OJP become imbricated and thrust northwards with the North Solomon (Vitiaz) trench marking the junction between imbricated and non-imbricated OJP crust. The Solomon arc is thrust northwards over imbricated OJP crust whilst deeper OJP crust is subducted. (b) and (d) (latter based on the Caribbean/Aruba example of Beets et al., 1984) depict a possible future scenario where subduction back-steps causing subduction fluids to impregnate the lower parts of the OJP crust causing garnet granulite and eclogite formation (Saunders et al., 1996): the resulting higher densities may encourage more wholesale plateau subduction. Figure based on Saunders et al. (1996).

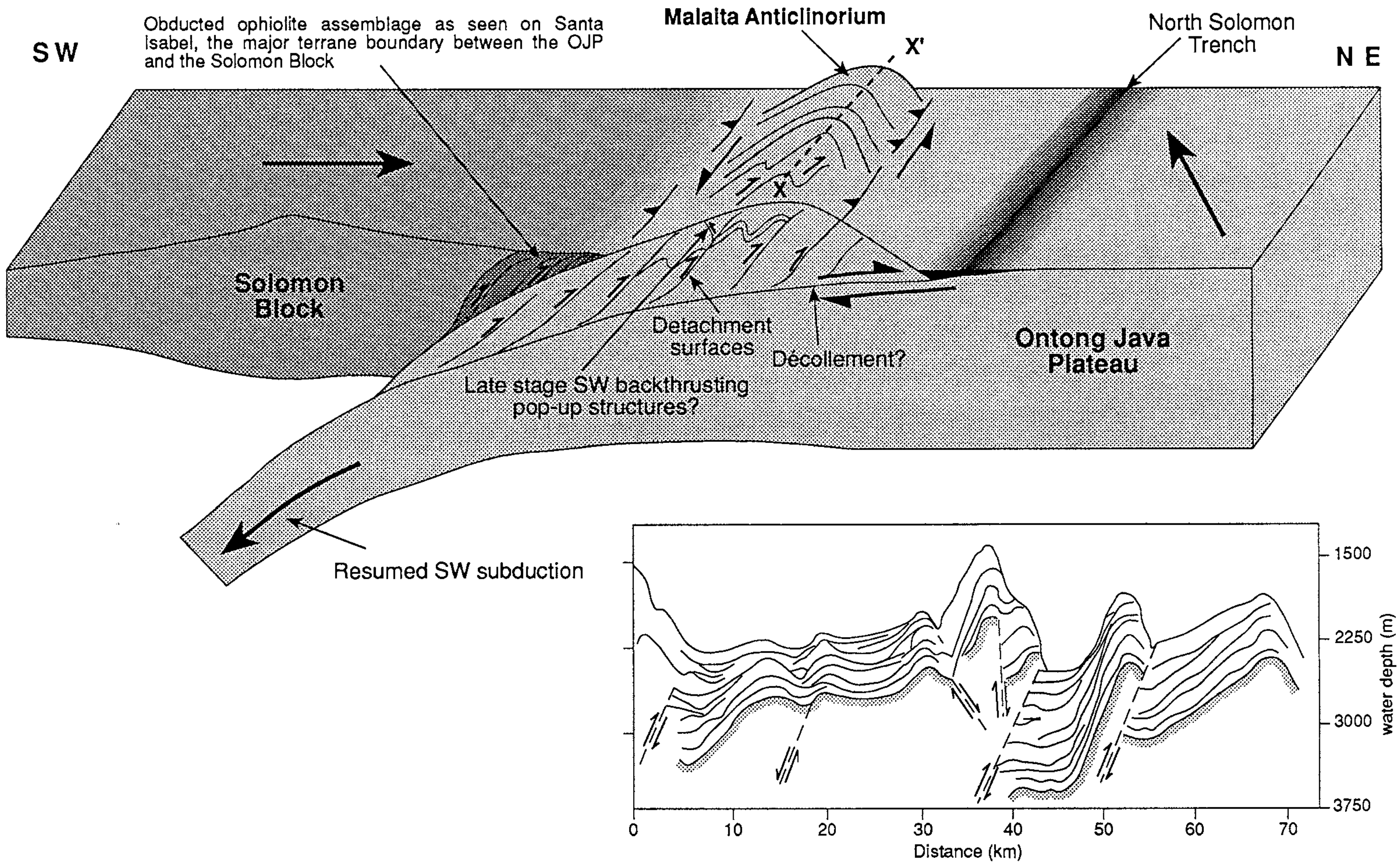

Fig. 15. Detailed accretion model for the OJP–Solomon arc collision. The compressional 'hard docking' event causes by an increase in the coupling between the Solomon block and the OJP began at around 4 Ma, resulting in the imbrication of NE-verging thrust sheets and the emergence of the Malaita anticlinorium. Upright to overturned, asymmetrical fold vergence predominates towards the NE on Malaita, with NW–SE axial planes (*X*–*X*′). Later-stage SW-directed backthrusting could be the result of small pop-up structures within the anticlinorium. Insert shows NE-verging thrusting in the OJP and its overlying sedimentary sequence offshore on the anticlinorium (Kroenke, 1972). (Reproduced from Babbs, 1997.)

ing the Early Miocene as the OJP encroached the trench and choked the subduction zone (Fig. 12). Evidence from Malaita suggests that this initial collision was of a 'soft docking' nature with little compressional deformation (Sopacmaps, 1994; Kroenke, 1995; Petterson et al., 1997; Neal et al., 1997). Continued, intermittent southwest-directed subduction is demonstrated by (a) the presence of Miocene–Pliocene volcanic rocks on Choiseul which are most likely linked to subduction at the Vitiaz trench, (b) seismic data for the area around Santa Isabel, Malaita, and Makira, and (c) recent swath mapping data from east of Makira, (Cooper and Taylor, 1984; Sopacmaps, 1994; Miura et al., 1996; Mann et al., 1998). However, the predominant subduction zone switched from the Vitiaz to the SSTS during Late Miocene times (possibly at around 8–6 Ma in the Solomon Islands area) and changed polarity becoming northeast-directed (Fig. 12). Thus the Australian plate now subducts beneath the Pacific plate and what used to be back-arc is now fore-arc (e.g. Makira).

The subduction of young (<5 Ma) Woodlark basin ocean crust produced a spectrum of unusual magmatic compositions (e.g. high-Mg ultrabasic lavas, high-Na–high-Ti basalts; Johnson et al., 1987; Crook and Taylor, 1994), leaky transform fault arc magmatism on the downgoing plate (e.g. the calc alkaline material present within the Woodlark basin; Crook and Taylor, 1994), an anomalously small arc–trench gap (e.g. the active Kavachi volcano is only 30 km from the subduction zone, Fig. 2), and rapid uplift rates along the frontal arc (e.g. Guadalcanal and Makira). This second and latest stage of arc activity has resulted in: (1) a second major stage of arc crustal growth within the tholeiitic basement + stage 2 Vitiaz arc SSMT; (2) new arc additions to the stage 1 arc-dominated CST; (3) sialic crustal growth within the basic Makira Terrain; and (4) the generation of new juvenile crust to the Solomon block, namely the New Georgia Terrain.

5.2. Accretion of the Ontong Java Plateau Terrain

Petterson (1995), Petterson et al. (1997) and Neal et al. (1997) suggest that whilst an initial 'soft docking' between the OJP and the Solomon arc may have occurred at c. 25–20 Ma (Fig. 12), the main 'hard docking' collision occurred around 4–2 Ma and is continuing today (Miura et al., 1996; Mann et al., 1998). The exact mechanism of accretion is a subject of ongoing debate and research (Miura et al., 1996; Mann et al., 1998) and it is useful in this paper to review possible accretion models (e.g. Fig. 14). Fig. 14a presents the obduction model suggested by Petterson et al. (1997) in which the OJP splits in two with deeper portions being subducted whilst shallower portions are obducted onto the Solomon arc. The SW-directed obduction in this model occurs after a period of NE-directed folding and detachment of the upper 4–10 km of OJP crust. The model presented in Petterson et al. (1997) was designed to explain both the NE-vergent folds present on Malaita (Petterson, 1995; Petterson et al., 1997) and late SW-directed thrusts imaged within the Malaita anticlinorium as imaged by the 1994 Sopacmaps surveys (Kroenke, 1995). Fig. 14b illustrates a possible future scenario in which the present collisional axis between the OJP and the Solomon arc becomes jammed and subduction backsteps to the edge of the OJP plateau. Fig. 14b is based partly on the Beets et al. (1984) model of the Caribbean plateau obduction based on data from Aruba (situated off the coast of Venezuela) which provide evidence for a younger arc sequence punching its way through obducted ocean plateau lavas (Fig. 14d). Such a scenario could theoretically cause hydrous subduction fluids to be introduced to the lower portions of the overlying OJP (or Caribbean plateau) crust transforming the lower crust into high-density garnet granulite or eclogite which may result in more wholesale subduction of the ocean plateau (e.g. Saunders et al., 1996). One model for OJP accretion which may more easily explain geophysical data recently acquired by Miura et al. (1996) Mann et al. (1998) and K. Suyehiro (pers. commun.) than the model presented in Petterson et al., 1997 is presented in Figs. 12 and 14b, and Fig. 15. Fig. 15 suggests that as the OJP approaches the Solomon arc and as compression increases the upper? 4–10 km becomes detached from deeper OJP crust and forms a series of NE-directed imbricate structures with accompanying large-scale asymmetrical NE-vergent folds as described from Malaita (Petterson, 1995; Petterson et al., 1997). In this model the North Solomon trench is envisaged as the boundary between detached and accreted OJP and OJP which is relatively unaffected by the plateau–arc collision. The intra-island Kaipito–Korighole fault exposed on Santa Isabel marks the only known subaerial exposure of the OJP–Solomon arc terrane (sensu stricto) boundary which has overthrust deep arc basement over accreted OJP crust.

5.3. General principles of intra-oceanic tectonic development

This paper highlights some of the general tectonic processes which have caused the present-day Solomon block to have been generated from the mantle and become amalgamated to its present form. The Solomon block terrain model allows a detailed analysis to be made of the tectonic evolution of the Solomon Islands. The following points are proposed relating to intra-oceanic tectonics, based on the Solomon Islands example:

(1) The basic roots or basement to a collage of arc terrains may be derived from a number of distinct oceanic environments, including non-arc related ones: e.g. plateau and MORB-like ocean crust.

(2) Oceanic plateaus may not obduct in their entirety, but may split into an upper, obductable layer and a lower subductable layer (e.g. Petterson et al., 1997). Which part obducts and which part subducts depends on the structure and composition of individual plateaus, the age of the plateau at the time of docking (as this affects the elevation of plateau crust (e.g. Neal et al., 1997), and the local tectonic setting.

(3) When plateaus obduct they may form a series of allochthonous blocks (e.g. Mann et al., 1998).

(4) An ocean plateau–arc docking need not necessarily be a highly compressional event. It appears that in the Solomons case there was a significant time lag between ‘soft’ and ‘hard’ docking events (Petterson et al., 1997).

(5) Switches in subduction polarity may not be a rare tectonic occurrence.

(6) A number of discrete plume-related events separated in time and space may be recorded within a terrain collage.

(7) Subduction zones may continue to be active, at least locally, for many millions of years after their main period of activity has ceased. This rejuvenation in subduction activity may produce two subduction zones with opposing polarities.

(8) Fold vergence and thrust directions may change with time as subduction polarities and related collisional vectors change (Petterson et al., 1997).

(9) Subduction of very young crust may produce a number of phenomena including unusual magma compositions, leaky fault systems within the downgoing subducting plate, small arc–trench gaps, and high rates of frontal arc uplift. This could produce widely differing levels of exposure within a single arc terrain, and large volumes of epiclastic materials which will survive as basin fills.

(10) Careful mapping and dating of ancient arc collages are required in order to reveal discrete periods of arc growth across the terrain collage.

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