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"IGNEOUS ROCKS, CENTRAL PLATEAU"

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Igneous rocks of basic character dominate the Central Plateau. A great dolerite sheet of Jurassic caps the Plateau and forms its resistant surface. Later, sporadic basalt lavas of Tertiary age fill old drainage depressions cut in the Plateau. The dolerite is far more voluminous, but less varied in its chemical composition (approx. 1500 cu. km; silica range 52-60%) than the basalts (approx. 15 cu. km; silica range 36-53%).

Both these rocks express important events which affected the Southern Hemisphere. The dolerite is the vast molten response to initial fracturing of the southern supercontinent, Gondwanaland, of which Tasmania is a small fragment. The basalts form part of the eastern Australian volcanic province which erupted in response to warping, stretching and increased heat flow along the continental margin as sea-floor spreading opened up the Tasman Sea and Southern Ocean, beginning about 85 million years ago.

JURASSIC DOLERITE

Its Structure

The dolerite sheet was probably intruded about 165 million years ago (McDougall, 1961). The sedimentary roof rocks, now largely stripped away, form remnants that are baked at the dolerite contacts, with sandstones converted to quartzites and mudstones to cherty hornfels. The dolerite upwelling was accompanied by block faulting. One of the largest movements forms the north-westerly trending Tiers Fault that bounds and uplifts the Plateau rocks by some 600m (McKellar, 1957; Carey, 1958a; Sutherland, 1966; Longman and Leaman, 1971).

The thickness of the dolerite varies considerably. Drilling and geophysical surveys show that the main sheet undulates and is generally 60 to 300 m thick, but thickens markedly under Great Lake (Carey, 1958a; Jones, Haigh and Green, 1966; Wiebenga and Polak, 1969). Here, a circular plug-like sheet between 1160 and 1280m deep form the central feeder for the dolerite, which appears to be a single intrusion. However, south and north of the Plateau and east of the Tiers Fault separated sheets appear (Prider, 1948; Fairbridge, 1949; Longman and Leaman, 1971). Peripheral feeders for the Plateau dolerite may exist at Long Lake, Mt. Gell, Little Billop and Mt. Arnon (MacLeod *et. al.*, 1961; Gulline, 1965; Longman and Leaman, 1971). South-east of Waddamana, a dolerite dyke occupies the Nelson Bend Fault and extends to the east as an extensive sheet (Fairbridge, 1949), but whether this is upstepping of a lower sheet or is a feeder rising from the basement is uncertain. Small dolerite intrusions in the Nive River near Bronte have locally dragged the intruded Triassic beds (Gulline, 1965). Later faults disrupt the dolerite in places, but movements are difficult to estimate where only dolerite is juxtaposed. Intersecting patterns of joint and fault lineaments have been mapped in the dolerite from aerial photographs (Prider, 1948; Voisey, 1949 a,b; Fairbridge, 1949; Blake, 1956; McKellar, 1957; Jennings, *et. al.*, 1961; Gulline, *et. al.*, 1963).

Its Petrology

The dolerite is silica saturated rock (tholeiite). Chilled, fine grained rock at the intrusive contacts passes up into coarser grained rocks which vary in mineral content and correspondingly in chemical composition. Hydro Electric Commission drilling for the Great Lake-Poatina scheme provided cores for detailed study of these variations (Joplin, 1957; McDougall, 1958, 1964). These variations resulted from fractional crystallization during cooling of the thick magma, by gravity settling of crystal aggregates and upwards concentration of the volatile-bearing residual components. This process produced large scale vertical zonation in the dolerite, gradationally forming the lower, central and upper differentiation zones (Table 1).

The dolerite contains variable proportions of pyroxene and plagioclase feldspar interspersed with iron-titanium oxides and a late-stage silicic, glassy to incipiently crystallized groundmass residue (mesostasis). The lower zone typically shows pyroxenes (orthopyroxene, augite and pigeonite) in excess over plagioclase (bytownite), with only minor mesostasis. The coarser central zone has plagioclase (labradorite) exceeding pyroxene (pigeonite and augite) and greater mesostasis. Very coarse "pegmatitic" dolerite, crystallized from volatile-rich residual magma pockets, is fairly common in the upper part of the central zone.

TABLE 5a Average Chemical Analyses of the Great Lake Dolerite Differentiation Zones.

Analysis	Chilled Base	Lower Zone	Central Zone	Upper Zone	Granophyre
SiO_2	53.2	52.6	54.3	53.7	59.2
TiO_2	0.7	0.5	0.8	0.7	1.5
Al_2O_3	14.5	14.2	15.9	14.5	11.4
Fe_2O_3	1.3	0.8	1.5	1.2	3.0
FeO	8.0	7.6	8.2	8.4	10.1
MnO	0.2	0.2	0.2	0.2	0.2
MgO	7.1	9.1	4.1	6.5	1.4
CaO	10.8	11.7	9.7	10.7	5.7
Na_2O	1.6	1.2	2.0	1.7	2.3
K_2O	1.2	0.8	1.3	0.9	2.3
P_2O_5	0.2	0.1	0.2	0.2	0.3
H_2O^+	1.1	0.9	1.2	1.3	1.4
H_2O^-	0.8	0.5	0.7	0.7	1.8
Total	100.7	100.2	100.1	100.7	100.6
No of Analyses	2	22	13	2	2

TABLE 5b Average Mineral Percentages in Differentiation Zones in the Great Lake Dolerite.

Mineral	Lower Zone	Central Zone	Granophyre
Clinopyroxene	43.0	23.9	13.1
Orthopyroxene	5.0	-	-
Plagioclase	42.5	44.3	16.6
Mesostasis	10.1	29.5	65.8
Iron Oxide	9.5	2.3	4.2
Olivine	-	-	0.3

Calculated from Analyses listed in Tables 5-7, Mc Dougall, 1964.

The resulting variations in chemical composition of the zones is illustrated in Table 5 by average analyses from 41 Great Lake dolerites (McDougall, 1964). The analyses demonstrate decreasing amounts of early crystallizing constituents (Mg, Ca) in the lower zone to increasing later constituents (Si, Al, Na, K) in the central zone. East of Inlet Trig on the eastern shore of Great Lake, the dolerite shows extreme differentiation into the silicic end product, granophyre. Here, residues streamed up into a structural high and then crystallized rapidly with loss of volatiles through the fractured roof.

These variations in the Great Lake dolerite are also reflected in measurements of the density and magnetic components in the rocks (Jaeger and Joplin, 1955; Jaeger and Green, 1958; Jaeger, 1964). Trace element studies on the Great Lake dolerite (Heir, Compston and McDougall, 1965) show Th, U, K, Rb and Sr isotope ratios more typical of crustal rocks than basic magma generated in the earth's mantle. This surprising result suggests either an unusual contamination of the magma before ascent or a mantle source of unusual composition under Tasmania.

Its Cooling and Subsequent History

On intrusion at temperatures close to 1100°C (McDougall, 1958), the dolerite would have solidified and cooled over an extended period of time. Calculations suggest that the main sheet would take between 1,000 and 1,500 years to solidify, compared with up to 20,000 years for solidification of the thick central part, while about 100,000 years would be needed for the main sheet to cool down to temperatures of about 200°C (D.E. Leaman, pers. comm.). The characteristic columnar jointing of the dolerite includes cooling joints, but these are difficult to distinguish from the jointing due to later uplift (Carey, 1958b; Hale, 1958).

The dolerite acquired magnetism on cooking through the Curie temperature, when its susceptible minerals were magnetized in the direction of the earth's field. This magnetization has been useful in deciding whether dolerite on the Western Tiers was actually in place or had moved under gravity (Jaeger and Green, 1958) and it also shows the south pole to have seen only 10° SE of Tasmania at the time of dolerite intrusion (Irving, 1956).

Secondary minerals now fill joints, cavities and alteration zones in the dolerite and include calcite, clays, zeolites, and chloritic materials (Hale and Spry, 1964). Some of these may have formed from final-stage fluids escaping from the consolidated dolerite, but others formed well after cooling and jointing, some perhaps forming during later regional heating of Tasmania to temperatures up to 200°C.

TERTIARY BASALTS

Lavas, explosive deposits and plugged vents form a scattered record of Tertiary volcanism on the Central Plateau. The basaltic types encompass the widest range known in Tasmania and includes some rare rocks. The volcanism has been thought to include some comparatively young eruptions, probably Pliocene or younger, but recent isotope (K/Ar) measurements on some of the lavas gave mid-Tertiary ages and upset this notion. The basalts conveniently separate into (a) isolated, strongly undersaturated plugs, (b) restricted unsaturated lavas and (c) widespread lavas forming piles dominated by saturated basalts. The range in chemistry of the rocks is illustrated by the analyses listed in Table 6, some of which are previously unpublished.

Strongly Unsaturated Plugs

These form small conical hills rising above the dolerite surface at Shannon Tier and east of Laughing Jack Marsh. They appear to represent completely denuded volcanoes that existed prior to the mid-Tertiary flow sequences. Recent magnetic measurements on the Shannon Tier plugs gave a steep magnetic inclination (with normal magnetization) that suggests a Lower Tertiary age (Wyatt, 1971).

The Shannon Tier rocks are celebrated for their rare petrology (Edwards, 1950) and luckily were amongst the earliest basalts investigated in Tasmania (Twelvetrees, 1902). The outcrops are descriptively named The Haystack, Beehive and Anthill and are composed of olivine-monticellite-nepheline melelitite rock (Analyses 2-4). The largest plug shows coarser patches of late-stage zeolitic rock. The unusual mineralogy of the plugs reflects the very low Si and high Ca in their chemical composition, which allowed

TABLE 6. Chemical Analyses of Central Plateau Tertiary Volcanic Rocks.

	Strongly Unsaturated Plugs				Unsaturated Lavas			Saturated and Transitional Lavas			
Analysis Number	1	2	3	4	5	6	7	8	9	10	11
SiO_2	37.1	36.0	36.2	37.6	43.9	46.8	46.8	48.6	50.1	51.5	52.3
TiO_2	2.6	1.1	2.2	3.8	2.4	2.5	2.7	1.8	1.8	1.6	1.7
Al_2O_3	9.3	15.2	11.9	15.3	12.9	13.7	14.1	13.9	13.6	14.2	14.2
Fe_2O_3	4.1	5.9	11.4	5.6	4.7	5.2	3.3	2.4	2.5	1.1	1.4
FeO	9.0	9.6	4.2	6.7	7.9	7.3	8.9	9.9	9.1	10.2	9.5
MnO	0.2	0.2	-	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
MgO	15.9	8.6	14.2	4.8	8.3	8.7	7.0	8.6	8.3	7.1	6.9
CaO	12.8	15.5	11.5	14.1	8.2	7.2	7.7	8.2	8.6	8.5	9.3
Na_2O	3.7	4.2	5.4	3.8	3.8	4.2	3.2	2.7	2.4	2.5	2.5
K_2O	1.4	1.9	2.1	0.9	2.2	1.7	1.8	0.8	0.5	0.9	0.6
P_2O_5	1.3	1.4	0.8	1.0	1.4	0.9	1.0	0.3	0.3	0.2	0.2
H_2O+	1.9	0.6	-	5.6	3.1	1.0	2.7	0.7	1.0	0.7	0.3
H_2O-			-	1.2				1.2	1.2	0.4	0.8
CO_2	-	-	-	-	-	-	-	0.3	0.2	0.9	0.2
Total	99.3	100.2	99.9	100.7	99.0	99.4	99.4	99.6	99.8	100.0	100.1

1. Olivine Melelitite, E. of Laughing Jack Marsh, Bronte; 2. Monticellite Olivine Nephelinite, Shannon Tier; 3. Olivine Melelitite, Shannon Tier; 4. Melilite Fasinite, Shannon Tier; 5. Mafic Feldspathoidal Mugearite, E. of the Nipples, W. of Antill Ponds; 6. Mafic Mugearite 3 kms. NE of Interlaken; 7. Limburgitic Basalt, Dogs Head Point, Lake Sorell; 8. Transitional Olivine Basalt, top flow, Liawenee Hill; 9. Tholeiitic Olivine Basalt, Flow Foot Breccias, SE Canal Bay, Great Lake; 10. Tholeiitic Olivine Basalt, E. of Shannon Lagoon; 11. Tholeiite, S. bank, Ouse River, Skittleball Plains. Analyses 1, 5-7 by P. Beasley and E. Kiss, Australian National University, Analyses 2-4 from Edwards (1950), Analyses 8-11 from Sutherland and Hale (1970).

crystallization of the undersaturated calcium silicate minerals monticellite and melelitite.

The Laughing Jack Marsh outcrop has only been located recently and is olivine-melelitite (Analysis 1). It differs from the Shannon Tier rocks in containing common inclusions of peridotitic rock (lherzolite) which probably represent accidental fragments brought up from the earth's mantle. It is one of the most basic volcanic rocks yet found in the Australian Tertiary.

Unsaturated Lavas

These lavas are mainly found on the SE side of the Plateau, where they were mapped by Nye (1921), but some also fringe and intersperse with the saturated lava sequence further west. The flows are associated with some plugs and the rocks fall into two associations, normal alkaline olivine basalts and more alkaline rocks. Many of the rocks, particularly the alkaline ones, contain peridotitic inclusions brought up from the mantle.

Typical examples of the normal alkali basaltic rocks include the basal flow of the Lake Echo sequence, some flows around Lake Augusta, that descended into the Liawenee sequence (Sutherland and Hale, 1970) and the limburgitic basalt at Dogs Head Point, Lake Sorell. This last rock (Analysis 7) carries large crystals of clinopyroxene, crystallized and brought up from depth.

The alkaline rocks commonly contain sodic plagioclase (oligoclase) and includes some unusually mafic types that have only been sparsely recorded in the world literature from a few scattered localities. They include nepheline and analcite mugearites (Analysis 5) and mafic mugearites (Analysis 6), as well as types grading to basanites and potassic olivine nephelinites or to more normal mugearites that lack peridotitic inclusions and are more typical of types evolved by fractionation of magma at higher levels in the crust.

Saturated Lavas

These form by far the most abundant flows on the Plateau. Their repeated eruption filled old valleys of the Nive, Ouse and Shannon Rivers with lava sequences reaching up to 400m thick towards Tarraleah (Prider, 1948;

Fairbridge, 1949; Voisey, 1949a; Jennings, 1955). The lavas mainly cooled into massive, commonly columnar flows with scoriaceous surfaces, but where they plunged into rivers, ponded drainages or lakes the resultant extra chilling produced characteristic lava forms.

Minor developments of water-cooled lavas are exposed in the Nive sequence on the Lyell Highway, but the most extensive developments occupy the lower parts of the Great Lake depression, suggesting eruption into old lakes. The rocks take two main forms, bedded water-laid tuffs (hyaloclastites) and dipping flow foot (pillow) breccias. The tuffs contain glassy shards scattered by steam explosions as water contacted molten lava and they show current scoured bedding and soft sediment deformations arising from loading, slumping and sliding. They represent emergence of volcanic vents above lake waters and pass upwards into the next phase during which flow foot breccias erupted. The breccias are spectacular rocks in which lobes of lava with glassy cooling crusts have been broken up and embedded in a matrix of glassy fragments. They formed when lavas from emerged vents plunged down from air into water, building out successively into lava deltas radiating out from the vent. Finally, when these deltas emerged subsequent eruptions formed normal air cooled lavas that cap the sequence.

These sequences were particularly well exposed by the drastic fall in the Great Lake water level during the 1967-68 drought (Sutherland and Hale, 1970), but have since been re-drowned. An older series of flow foot breccias, however, is exposed in the banks of the Ouse River and in Liawenee Canal and is conspicuously infiltrated by secondary minerals. The mineral assemblage included calcite, apophyllite, zeolites (chabazite, phillipsite), clays (nontronite) and hydrated calcium silicates, notably the extremely rare unstable species tacharanite and its breakdown products (Sutherland, 1965; Sutherland and Hale, 1970).

Several flows at Great Lake have been recently dated by K/Ar isotopic measurements and give important controls on the age of volcanism, formation of the Great Lake depression, development of the pre-basaltic erosional downcutting (Sutherland, Green and Wyatt, 1972). The dates, in decreasing order of age, come from the lowest flow at Skittleball Plains (23.6 million years), the top flow of the Liawenee sequence (22.9 m.y.), the flow capping Reynolds Island (22.3 m.y.), a dyke cutting flow foot breccias on Reynolds Island (21.8 m.y.) and the flow capping hyaloclastite tuffs and baked Tertiary sediments from Tods Corner to Shannon Lagoon (21.8 m.y.). This indicates eruptions from at least Late Oligocene into earliest Miocene times. Some magnetic measurements on the dated lavas show largely normal magnetization with magnetic inclinations typical of those expected from rocks with mid-Tertiary ages.

The eruptive points for the saturated flow sequences are mostly unexposed, except at Great Lake where several vents suggest fissure eruptions located on intersecting lineaments (Sutherland and Hale, 1970). A few possible feeder dykes have been suggested in the Nive Valley north of Tarraleah (Prider, 1948) and a possible plug lies NW of Bronte Park (Gulline, 1965). Petrographically the lavas include tholeiitic and transitional olivine basalts and true orthopyroxene-bearing tholeiites (Analyses 9-11), with the most saturated basalts approaching compositions similar to that of the Jurassic dolerite.

Later faulting of any significance does not seem to have disturbed the basalt piles. Fairbridge (1949) thought that post-basaltic faulting may have formed the Lake Echo depression, based on the apparent absence of any filling basalts. However, a small flow remnant recently located west of Lake Echo Farm and well below the main basalt outcrop makes this uncertain (Sutherland, 1971). This remnant resembles the top tholeiitic olivine basalt capping the succession to the east and suggests overtopping down into the Lake Echo depression.

CONCLUDING STATEMENT

The igneous rocks of the Central Plateau are all mafic in character, but provide an interesting comparison in behaviour of mafic magma introduced in large voluminous intrusions and in smaller scattered volcanic eruptions. Studies of these Central Plateau rocks have played an important part in understanding the structural, magmatic and erosive history of Tasmania since the early part of the Mesozoic Era.

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