SUB-BASALTIC WEATHERING, DAMSITES, PALAEOMAGNETISM, AND THE AGE OF LATERITIZATION

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(With 1 Table and 2 Figures)

(MS received 19 July 1976)

ABSTRACT

Investigations described from three Victorian damsites indicate that weathering of Ordovician bedrock is increased where it is overlain by basalt, even though the basalt is little weathered. Sub-basaltic weathering may account for the fact that weathered rock beneath a Jurassic lava flow gives a weathering remagnetization age of Mid-Cainozoic, consistent with palaeomagnetically determined ages of lateritization from elsewhere in Australia.

The weathering of a rock may be affected by its structural and topographical relationship to other rocks. Thus a cap rock may protect a lower stratum from wetting, and hence weathering, or may concentrate water along certain zones whose disposition follows features in the cap rock rather than the lower rock. A lower rock may also be affected by leachates derived from overlying rock. Thus both structural and lithological features may be relevant in the mutual effect of rocks in weathering.

Examples of this effect have been revealed during investigation and construction of three dam sites in Victoria, where it was found that weathering of Ordovician shales and mudstones is increased beneath little-weathered Newer Basalt lava flows. Rosslynne Dam is on Jacksons Creek, 2 km upstream from Gisborne; Tullaroop Dam is 8 km southeast of Carisbrook on the Tullaroop Creek, a tributary of the Loddon River; Eppalock Dam is 30 km east of Bendigo, on the Campaspe River.

Rosslynne, Tullaroop, and Eppalock dam foundations are composed of rocks of identical geological age, and all three damsites are in valleys which have been eroded along the junction between Newer Basalt flows and Ordovician sedimentary rock. In every case the rivers have cut across a minor tongue of basalt, forming a basalt outlier on one side of the valley (Fig. 1).

Rosslynne and Tullaroop Dams were constructed between the basalt outlier and the main lava flow, and the Eppalock Dam was constructed downstream from the outlier. Thus at Rosslynne and Tullaroop, both sides of the valley are capped by basalt, which covers thin Tertiary unconsolidated sediments over a bedrock of Ordovician age. The section on the western abutment at Eppalock is the same as at the other two sites but the eastern abutment is directly on to Ordovician rocks.

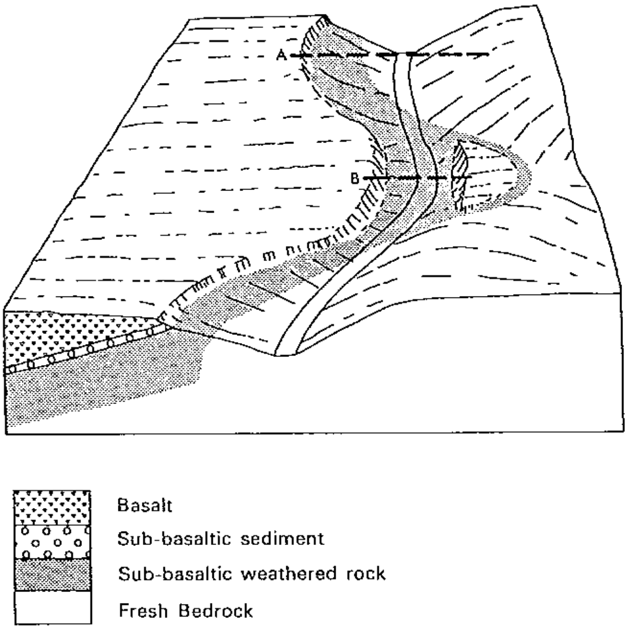

Fig. 1. The relationship between basalt and soft-weathered rock. A = The Eppalock Dam situation; B = The Tullaroop Dam and Rosslynne Dam situation.

The foundation excavations in the Ordovician sediments at Eppalock revealed that the weathered rock changed abruptly from soft, which could be crumbled in the hands, to hard, which rang dully under a hammer blow. The junction of the soft and hard weathered zone crosses the strike of the beds. On the western side of the floor of the dam excavation the soft weathered rock extended for 7 m below the surface, and on the western abutment was encountered in bores down to 20 m, but on the eastern side there was only 2 m of soft weathered rock. At Tullaroop soft weathered rock was present to depths of 12 m on the floor of the valley, and over 20 m on the valley sides.

Journal of the Geological Society of Australia, Vol. 23, Pt 4, pp. 367-370, December, 1976.

Soft weathered rock continued below bores drilled to 45 m at Rosslynne. Details of the distribution of soft weathering in relation to geology and topography are shown in Figure 1.

This distribution of weathered rock suggests two possibilities:

(a) The soft weathered rock was originally of uniform thickness and has been eroded where not protected by the basalt.

(b) There has been an increase in the weathering of Ordovician rocks beneath the basalt.

Since deep, soft-weathered rock is found under both the main basalt flow and outliers of basalt, and also on the eroded slopes between the main flow and the outliers, and yet is absent from all valley sides that never had a basalt cover, the second possibility seems the more probable. Furthermore, if the soft-weathered zone were pre-basaltic, it would be expected that the weathered zone would persist along the old depression beyond the outlier of basalt, but it does not. In excavations it was found that the base of the soft-weathered zone dipped steeply precisely at the presumed position of the original basalt edge, at a gradient that could not have been parallel to an earlier valley side. In fact the distribution of the weathered material is such as to suggest that the edge of the soft-weathered rock is almost identical with the original edge of the basalt flow.

This coincidence of boundaries can be usefully applied in two ways. The soft-weathered zone boundary can be used as an indicator of the limits of a now eroded lava flow, even in areas where the exact relationship is not clear. The knowledge that there is a possibility of the sedimentary rocks under basalt being soft and weathered could aid the civil engineer in foundation investigations.

Sub-basaltic weathering should, perhaps, not be so surprising, but its significance is not always appreciated by geologists and engineers. A normal weathering profile is expected to be most weathered at the surface, and the degree of alteration should decrease systematically with depth. But because of the ease of water passage many lava flows—almost all the ones investigated in Victoria—are relatively fresh at the top, more weathered near the base, and sub-basaltic weathering may be greater still.

Some geological interpretations may be simplified by an understanding of sub-basaltic weathering. In a paper on the southern tablelands of New South Wales, Browne (1972) writes 'One circumstance, the significance of which has not been satisfactorily explained, is the frequency with which at the base of the sub-basaltic column white clay is found resting on leached bedrock and overlain by gravelly or sandy deposits'. Obviously the sub-basaltic weathering described in this paper could provide an explanation.

Dailey, Twidale & Milnes (1974) describe weathering from beneath basalt dated isotopically as Jurassic, from which they conclude that lateritization may date from the Jurassic. This is surprising as it is generally thought that lateritization in Australia is restricted to the Cainozoic, so it may be worth considering the possibility of sub-basaltic weathering. 'The Late Palaeozoic glacigene sediments beneath the basalt are highly weathered, leached, bleached, and kaolinised' according to the authors, but 'no complete lateritic profile, namely pisolitic capping, mottled, and pallid zones, has been located in the Late Palaeozoic glacigene sediments beneath the basalt'. The basalt has itself apparently escaped lateritization during the Cainozoic, when the process was active in other areas, and has no more than half a metre of soil with calcrete developed on it. However, the amount of surface weathering is little indication of the amount of sub-basaltic weathering that might have occurred, as at sites described earlier.

Further information on the age of weathering is provided by palaeomagnetism, which can provide tests for a number of possibilities. If the laterite profile has been truncated then later covered by the Jurassic basalt, the original magnetic directions dating from the time of lateritization should yield a palaeomagnetic pole position which accords with those from other Australian rock formations of that age, that is, Triassic (Daily *et al.*, 1974). Alternatively, if the sub-basaltic weathered zones dates from post-basaltic times (perhaps Cretaceous or Cainozoic) then the palaeomagnetic pole position determined from the original magnetic directions should fall on the appropriate segment of the Australian apparent polar-wander path. Partial thermal demagnetization results of eight samples collected from below the basalt on Kangaroo Island are given in Table 1. The pole position calculated from the stable directions is clearly different from the pole position expected from originally magnetized Triassic rocks (Schmidt, 1976), although the overlying basalts give a typical Jurassic direction (Fig. 2). The weathered material yields results similar to those determined from rock units elsewhere in Australia that were weathered in the late Cainozoic. The weathering on Kangaroo Island is thus younger than the overlying basalt and is probably the result of sub-basaltic weathering.

TABLE 1

Palaeomagnetic data from originally magnetized and remagnetized rock units

Rock unit	Geol. age	Mag. age	*Direction*				*Pole*		
			N	*R*	Dec (°)	Ind (°)	Lat. (°S)	Long. (°E)	A_{95} (°)
Kangaroo Is. basalt (S.A.)	J_m	J_m	20	18.92	288.7	—67:5	39.0	183.2	10.7
Kangaroo Is. laterite (S.A.)	R-J_1	J_m	8	7.92	183.2	56.2	86.9	76.9	8.4
Springfield Basin (S.A.)									
—brown clays	Tr_u	Tr_u	6	5.81	76.4	64.7	32.3	169.9	23.8
—red clays	Tr_u	T_m	6	5.99	185.2	56.1	83.7	96.5	2.8
			8	7.98	182.8	56.6	84.3	114.5	2.9
			5	4.95	202.8	57.7	70.3	73.6	8.6
			7	6.99	185.1	56.6	83.3	100.4	2.8
			5	4.97	16.3	—59.5	74.4	85.0	6.3
			6	5.98	181.9	56.9	84.3	122.8	3.8
—mean of red clays			6	5.96	188.8	57.4	80.4	90.5	5.6
Perth Basin sediments (W.A.) —mean of sites	P-K	T_m	14	13.91	181.2	55.5	81.2	108.8	4.5
Montejinni limestone (N.T.)	$Є_m$	T_m	12	11.04	186.3	47.7	76.4	107.2	14.1

Note: N is the number of samples and *R* the resultant of their unit vectors. A_{95} is the half-angle of the 95 percent core of confidence.

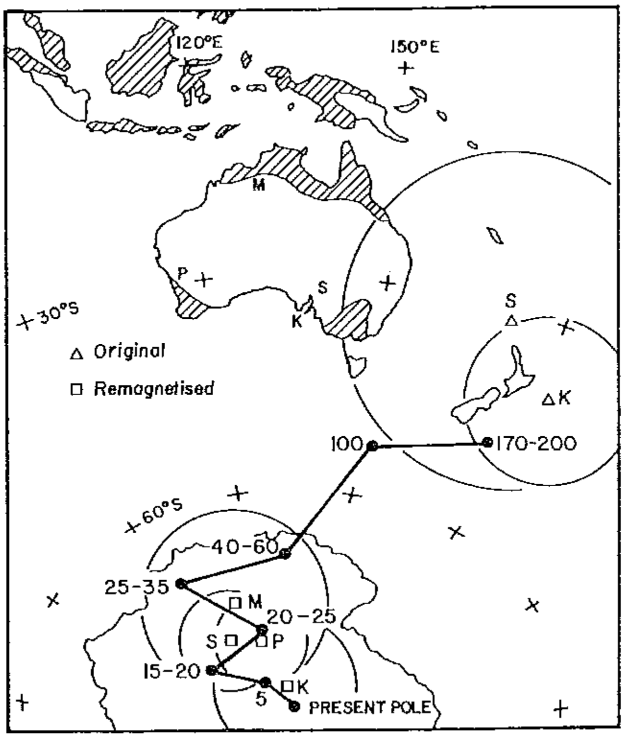

Fig. 2. P—Perth Basin (Schmidt & Embleton, 1976), S—Springfield Basin (this paper), K—Kangaroo Island (this paper), M—Montejinni Limestone (Luck, 1970). Shaded region represents approximate extent of present day lateritic soils. The mid-Mesozoic (170-200 m.y.) to present segment of the pole path is plotted for comparison with pole positions given in table 1.

Samples of red clays from the Springfield Basin near the Flinders Ranges of South Australia yield a palaeomagnetic pole after partial thermal demagnetization, suggesting weathering of Upper Triassic rocks during the period 25-15 m.y. (Late Oligocene-Early Miocene). Samples of brown clays, after partial thermal demagnetization, and correcting for bedding tilt, give a pole position which is in accord with their geological age (Fig. 2) indicating that their stable magnetic directions are records of the direction of the magnetic field at the time of formation.

Schmidt & Embleton (1976) found that rocks ranging in age from Early Permian to Middle Jurassic in the Perth Basin recorded very similar palaeomagnetic directions. The fact that tectonically tilted rocks gave the same result as undisturbed ones indicates that the measured directions were not true records of the primary magnetic field at the time of rock formation: they record a remagnetization event in post-Jurassic times. The most probable event that could lead to remagnetization was the period of lateritization. When plotted on the Tertiary apparent polar-wander path for Australia (Fig. 2), the Perth Basin data fall near the path segment representing 25 to 20 m.y. (Late Oligocene). Luck (1970, reported *in* Schmidt & Embleton, 1976) found a similar direction for remagnetization of Palaeozoic strata in the Northern Territory.

All these data suggest a synchronous remagnetization event for a large area of Australia, perhaps all Australia, and suggest that the dominant period of lateritic weathering was Late Oligocene to Early Miocene.

ACKNOWLEDGMENTS

We acknowledge the assistance of the State Rivers and Water Supply Commision of Victoria for supplying dam-site data, the Geological Survey of South Australia for supplying geological information in South Australia, and thank Dr C. T. Klootwyk and Mr J. Kirschvink for collecting material for the palaeomagnetic measurements from the Kangaroo Island laterite. P.W.S. acknowledges the receipt of an A.N.U. Ph.D. Scholarship while carrying out the palaeomagnetic work recorded here.

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