DARLOT DISTRICT, WESTERN AUSTRALIA

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INTRODUCTION

The Darlot district lies some 300 km north of Kalgoorlie, centred on latitude 27°55'S and longitude 121°15'E within the SIR SAMUEL (SG51–13) 1: 250 000 map sheet area. The following summary is based on regolith–landform mapping, regolith characterisation, and landform evolution studies conducted in the district for Homestake Gold of Australia Limited (King, 1999; Krcmarov *et al*., 2000). This work supplements regolith–landform and geochemical mapping of SIR SAMUEL by Craig and Churchward (1995) and Kojan *et al*. (1996).

PHYSICAL SETTING

Geology

The Darlot district lies at the southern end of the Yandal Supracrustal belt of the Archaean Yilgarn Craton. The deformed and metamorphosed late Archaean volcano-sedimentary succession at Darlot comprises a mafic package of commonly pillowed tholeiitic basalts and thin dolerite sills, and an upper, felsic–intermediate package of dacitic lavas and volcaniclastic rocks, broadly separated by a 500–600 m thick, internally differentiated dolerite sill. The sequence is folded about open, shallowly NNW-plunging folds, and is intruded along its eastern and southern margins by Archaean granitoids. Felsic–intermediate porphyry and lamprophyre intrusions are common within the sequence (Krcmarov *et al*., 2000).

Geomorphology

The terrain in the Darlot district is gently undulating. The greatest relief is provided by belts of hills within the granitoids and a prominent south to southwest facing breakaway in greenstone rocks immediately east of the Darlot Mine. Restricted erosional tracts extend south from this breakaway as low hill belts that give way southwards to gently sloping interfluves, thinly mantled by debris from the immediate hinterland. The breakaway flanks a broad palaeovalley, lying generally along the keel of the Darlot Syncline within greenstone rocks adjacent to the enclosing granites. Slopes within the palaeovalley are mainly mantled in their upper part by ferruginous saprolite and some ferricrete. This material merges downslope with colluvial units derived by erosion of the upslope parts. The topography north of the palaeovalley is dominated by extensive, very gentle slopes that gradually merge with broad alluvial floors. The upper reaches of many of these slopes have eroded into breakaways and planar surfaces have developed mostly in indurated saprolite or more rarely in fresh bedrock.

The broad alluvial floors and associated expansive outwash plains separate areas of relief from Lake Darlot, which lies immediately northwest of the district. East–west trending, longitudinal, quartz-rich kopi dunes encompass the margin of Lake Darlot.

Climate and vegetation

The climate is semi-arid, with hot summers and mild winters. The mean annual rainfall of 210 mm falls mainly in the summer months during erratic thunderstorms and cyclonic activity. The mean daily maximum temperature is 36°C in January and 18°C in July.

Vegetation in the area is characteristically sparse, low acacia woodlands dominated by mulga (*Acacia aneura*). The shrub layer is dominated by bluebush (various *Chenopodiaceae* spp.), rattle bush (various *Cassia* spp.), and poverty bush and turpentine (various *Eremophila* spp.).

REGOLITH–LANDFORM RELATIONSHIPS

Regolith–landform relationships were mapped at 1:25 000 scale using aerial photograph interpretation, airborne radiometric and magnetic imagery, and Landsat TM imagery substantiated by ground traverses. Several regolith–landform mapping units were identified. The regolith materials that comprise these units are either zones of a profile developed by the *in situ* weathering of bedrock, consolidated transported debris (e.g. ferricrete), or unconsolidated transported debris, parts of which are secondarily cemented (e.g. hardpanised colluvium). Regolith–landform units have been classified into three major groups, which are described below.

1. *Ferruginous duricrust and gravel*. Dark brown to black ferruginous duricrusts and gravels comprise approximately 2% of the mapped area and occupy drainage floors, or the flanks to these floors. Ferruginous duricrusts are either developed by ferruginisation of sediments (forming ferricrete) or by the weathering of bedrock and occur mainly above mafic rocks. Ferricrete can be distinguished from *in situ* laterite on the basis of (1) being predominantly composed of hematite, (2) having maghemite beneath and in the base of the ferruginous cap, (3) lacking obvious goethitic cutans, (4) containing fine rounded quartz grains in spoil sourced immediately beneath the duricrust, and (5) having sedimentary structures and fabrics (see below). Such duricrusts are particularly siliceous when located adjacent to, or down gradient from, lamprophyric rocks. The duricrust surfaces are typically mantled by a veneer of gravel lags consisting of pisoliths and nodules and fragments of ferruginous saprolite.

2. *Ferruginous saprolite, saprolite and bedrock*. The regolith of ferruginous saprolite, saprolite and bedrock-dominated terrain is characterised by outcropping ferruginous saprolite, saprock and fresh rock, and subcropping saprolite. These materials occupy approximately 23% of the Darlot district, and occur respectively on breakaways, hills and pediments. Breakaways have developed

in both ferruginous saprolite and indurated leached upper saprolite above greenstones, with the former largely being contained within the palaeovalley. Non-ferruginous, leached upper saprolite lies outside the palaeovalley, where shallow, relatively open drainages traverse and locally incise pediments through headwater retreat to form breakaways. Isolated buttes of ferruginous saprolite preserved in partially truncated to stripped areas, attest to the original broader development of a deeply weathered mantle. Exposed saprock or bedrock is generally confined to granite terrain and immediately adjacent greenstones in topographically elevated areas. Elsewhere, greenstones are exposed some distance downslope from breakaways. Pediments within and outside the palaeovalley are commonly mantled by scree of ferruginous gravels, ferruginous saprolite, ferruginous lithic fragments and quartz. A metre or more of generally hardpanised sediments may bury the saprolite down slope. Pedogenic carbonate-rich soils are common over residual regolith materials, particularly in the exposed leached upper saprolite, and calcrete has developed over exposed mafic bedrock or saprock.

3. *Colluvial, alluvial and aeolian materials*. Mixed colluvial, alluvial and aeolian plains form the dominant regolith–landform units in the Darlot district, accounting for about 75% of the mapped area, and ranging in thickness from 5 to 40 m. Surfaces of the *colluvial–alluvial* units are strewn with a polymictic lag comprising quartz and ferruginous gravels, including maghemite gravels after ferricrete, ferruginous saprolite and ferruginous lithic fragments. These units typically overlie leached upper saprolite, with the coarseness and density of the lag, in particular that of its ferruginous lithic and quartz component, being a reliable indicator of the depth of cover. This colluvial cover also conceals earlier depositional regimes including palaeochannels, filled with megamottled clay-rich materials, a dolomitic claystone horizon and ferruginous detritus. The distribution of palaeochannels is deduced in the field from the presence of fine maghemite-rich pisolithic lag and minor quartz fragments that mantle red, clay-rich, Fe-rich soils. A slight topographic inversion is also apparent.

Aeolian sands form shallow drifts over the landscape and locally form dunes, particularly on the southern and eastern margins of playas. Soils developed in these deposits are often weakly calcareous or contain kankar as laminations or nodules.

REGOLITH CHARACTERISATION

Bedrock

Regolith in the granite terrain of the Darlot district is mostly stripped, or mantled by a skeletal feldspathic soil that commonly overlies fresh bedrock or saprock. In some areas, the weathering of granitic rocks has produced a fairly homogeneous, pale, kaolinite-rich saprolite profile, sporadically overlain by a weakly mottled, pallid clay zone. Silcrete is common in the top of this unit in such situations.

In contrast, regolith profiles over mafic rocks are increasingly ferruginous and brecciated towards the surface, with the local development of collapsed ferruginous saprolite at the surface. The mottled clay zone is absent, with materials underlying the ferruginous saprolite comprising locally collapsed and indurated leached upper saprolite. Ferruginous gravels, consisting mostly of variably sized and abraded ferruginous saprolite fragments, overlie ferruginous saprolite in most topographic positions, but, in topographically lower positions the ferruginous saprolite is commonly unconformably overlain by duricrust.

Profiles developed in felsic–intermediate volcanic and volcaniclastic rocks were not observed during the study.

Ferricretes

Ferricretes contain a variety of ferruginous clasts derived mainly from erosion of ferruginous saprolite and older duricrust (which may have been lateritic) upslope. The ferricretes typically comprise dark brown to black, hematite-and maghemite-rich nodules and pisoliths, and brown, goethite-rich fragments of ferruginous saprolite, set in either a dark brown goethite-rich matrix, or a red-brown silica-rich matrix, particularly where adjacent to lamprophyre. The unit has a clast-supported fabric and commonly becomes more indurated towards surface. It is also commonly graded, with predominantly nodular forms at the base (indicating a proximal source) to pisolitic at the top (indicating a distal source). The clast morphology, crude bedding and apparent sorting are indicative of a sedimentary origin. In some places, the unit unconformably overlies collapsed ferruginous saprolite or older sediments (see below), which are identified by the presence of fine rounded water-worn quartz grains.

Sediments

There are two principal sedimentary units (oldest to youngest):

1. Palaeochannel deposits are poorly crystalline kaolinite–smectite clays that are extensively megamottled. Some profiles show redox partitioning in the form of goethite-stained kaolinitic clays lying over green, reduced, partially saturated smectitic clays. The latter are probably associated with the development of perched watertables. Subordinate, rounded and water-worn, quartz grains up to 1 mm in diameter occur in the clays. A dolomitic claystone horizon is present towards the base of the channel and is up to 4 m thick, but little is known of its characteristics. Yellow-brown pisoliths are dispersed throughout the profile, except within the dolomitic claystone horizon. Cutans to these pisoliths are thin (<1 mm) and poorly preserved.
2. Quaternary sediments include alluvial channel deposits, aeolian sands and dunes, and colluvial talus and detritus shed from upslope during episodic flooding and sheetwash events. Colluvial and alluvial deposits generally fine upwards and may be subdivided into an upper, sandy clay component, and a lower gravelly component. The development of hardpan in this unit is widespread. It reaches a thickness of some 7 m, but is more commonly 3–4 m thick. Aeolian sands are concentrated along the margins of Lake Darlot and are

characteristically yellow-brown to red-brown, consisting of dominantly angular to sub-rounded quartz grains and lesser rounded resistate grains, mainly hematite and maghemite of lateritic origin.

REGOLITH EVOLUTION

Development of the regolith blanket in the Darlot District can be explained in terms of landscape evolution during a progression from a humid climate to present arid and semi-arid conditions. This model described below is drawn largely from Krcmarov *et al.* (2000), and is shown schematically in Figure 1.

Substantial erosion of the Darlot district under a former wetter climate produced a broad valley in those greenstones forming part of the Darlot Syncline. The valley was surrounded by an elevated granitic and marginal greenstone hinterland (Figure 1A). Locally-derived saprolitic and lateritic detritus choked the Carey palaeodrainage at a relatively early stage and resulted in the formation of Lake Darlot.

Broadly contemporaneous weathering of topographically higher parts of the greenstones in the hinterland and in the palaeovalley locally formed ferruginous nodules and pisoliths (Figure 1B). This material was subsequently mechanically dispersed into channels within the palaeovalley to form accumulations of detrital ferruginous pisoliths and nodules. Near-surface groundwaters

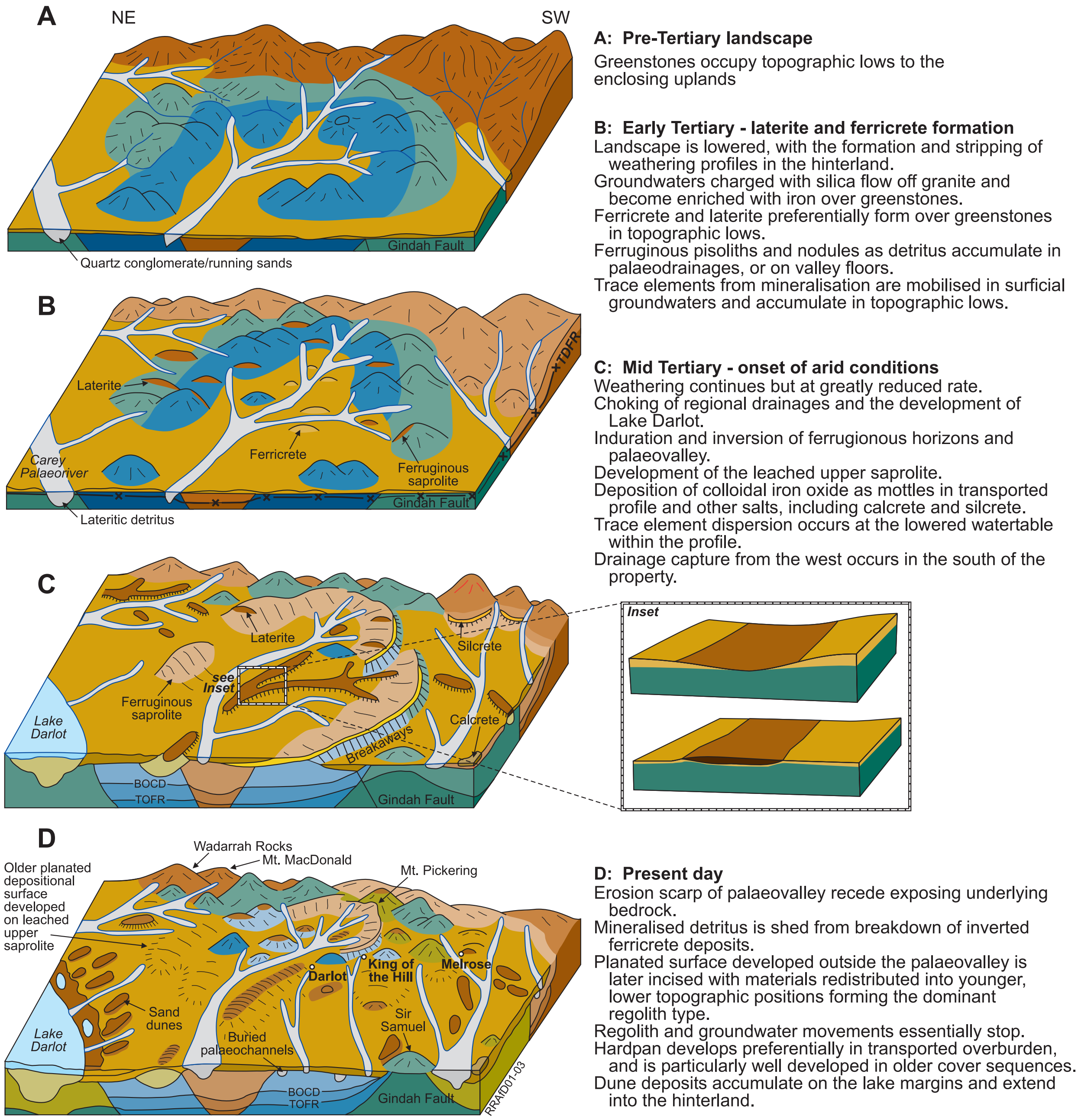

Figure 1. Interpreted history of landform evolution in the Darlot–Centenary region. Inset shows the principle of relief inversion, whereby an old valley floor is partially covered with alluvium and colluvium, which is then cemented by Fe-rich groundwaters to form ferricrete, thereby becoming more resistant to erosion and consequently inverted in the landscape.

leached iron and other elements from the greenstones, and migrated downslope through topographically lower bedrock and overlying detritus. During wetter periods, these leachates would have been flushed from the region, but the onset of arid conditions reduced the rate of groundwater migration. Water tables withdrew from upland areas, and groundwaters accumulated in topographic lows, invading and impregnating the upper parts of the weathering profile and overlying cover to form indurated (silicified) ferruginous saprolite and ferricrete, respectively (Figure 1B). This process protected the upper regolith from further erosion and it subsequently became topographically inverted through headwater erosion associated with either climatic change, tectonic uplift, and/or drainage capture and its associated change in base levels of erosion (Ollier, 1994; Pain and Ollier, 1995; Figure 1C). Thus ferricretes are mainly preserved in the original capture areas to palaeodrainages and therefore represent the uppermost part of the palaeodrainage systems. Groundwaters continued to contract away from topographic highs, contributing to the development of leached upper saprolite by draining through the uppermost part of the profile.

Increasingly arid conditions also dramatically slowed the rate of weathering, but erosion continued and significantly lowered the landscape around the palaeovalley by stripping the coarser-grained granitic hinterland to expose the underlying saprock and bedrock. Lake Darlot became a playa environment, and aeolian gypsiferous and quartz sands were deposited as dunes along the southern and eastern margins of the lake (Figure 1D).

Palaeochannels around Darlot are filled with lake clays to topographically higher levels than the present lake surface, implying that flooding was originally much more extensive than the present area of the lake, and the hydraulic gradient consequently somewhat lower. The dolomitic claystone is thought to have accumulated at a watertable during this time. The source of the Mg in the dolomite is likely to be the greenstones found within the palaeovalley. This stage in landscape evolution may be related to the planated surface, which may also have been shielded from deep incision because it lies between resistive, stripped or armoured greenstones in the east and in the south, respectively. The build-up of carbonate-rich soils and colluvium at the top of the profile indicates more arid conditions and the probable net drying of the profile, resulting from lower energy erosion and deposition.

The prolonged arid conditions increased the groundwater salinity within the catchment, and promoted the deposition within the profile of carbonate, silicate, sulphate and chloride salts (Butt, 1981). Evaporitic deposition of these salts as pedogenic carbonate, calcrete, silcrete and playa deposits occurs in water-unsaturated upper regolith, particularly in valleys, where it has overprinted the *in situ* materials (Lawrance, 1990).

Recent modifications to the landscape have largely involved the widespread dispersal of sheetwash and dune material, derived from a variety of sources. Hardpan is also widespread, developed particularly in the older, more stable, areas. Pedogenesis and erosion at the current surface has shed ferruginous detritus over broad areas.

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