Great Victoria Desert: new dates for South Australia's ?oldest desert dune system

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Introduction and background

Mineral exploration employing sampling for geochemical signatures in the Gawler Craton has been made more difficult by the presence of ubiquitous cover units. Of these, the Quaternary siliceous dunes of the Great Victoria Desert are a significant component that can cover up to 45% of the terrain with thicknesses to ~25 m (Figs 1, 2). The major lithostratigraphic dune-forming unit of the Great Victoria Desert in South Australia is the Late Pleistocene Wintrena Formation (Benbow, 1993; Benbow et al., 1995). This formation appears to have been stable for a considerable time and commonly contains a number of secondary calcrete horizons that may be geochemically anomalous in several metals (Benbow et al., 1995; Lintern et al., 2002).

Bowler (1976) assembled evidence, including radiocarbon analysis of soil carbonates, which indicated that the dune fields of southern Australia originated in Late Pleistocene times between ~17 500 and 16 000 yBP, and became stabilised at 13 000 yBP. However, it has been established that those secondary

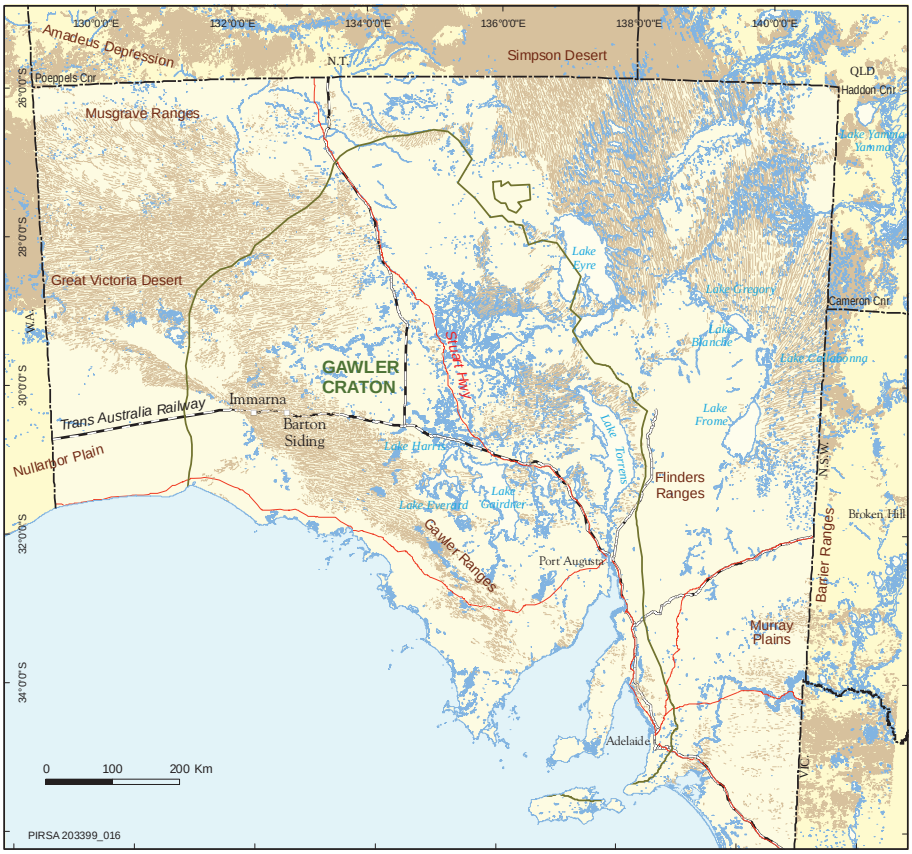

Figure 1 *Deserts and dune patterns in South Australia (after Twidale, 1971; Wasson et al., 1988; Pell et al., 1999).*

Figure 2 *Aerial view west over Immarna Siding, the Trans Australia Railway, and eastern Great Victoria Desert Quaternary longitudinal dunes overlying the Palaeogene Ooldea Range barrier sands. Immarna OSL site is arrowed. (Courtesy of MC Benbow; photo 403341)*

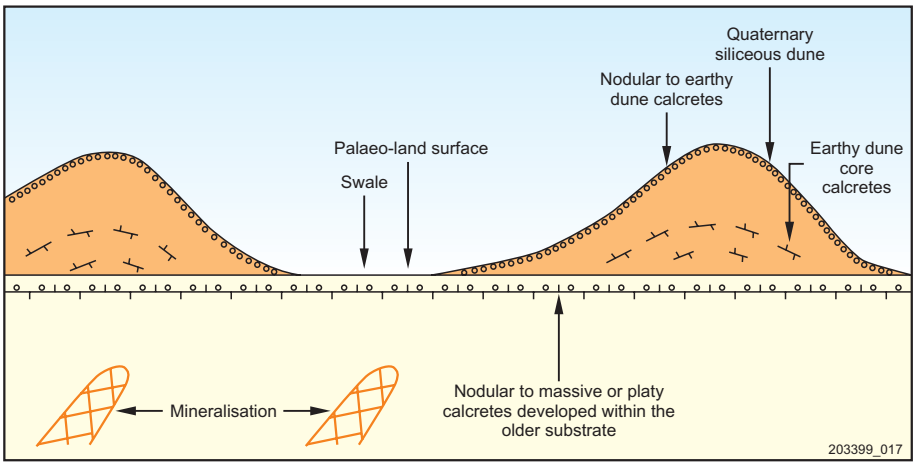

Figure 3 *Diagrammatic cross-section showing the significance of landscape position on calcrete sampling within dune fields.*

carbonates (calcretes) can be substantially younger than their host materials (Belperio and Bateman, 1986; Phillips and Milnes, 1988; Belperio, 1995; Sheard, 1995; Sheard and Bowman, 1996; Bourman et al., 1999). Stratigraphic and various palaeosol dating have suggested dune ages >125 000 yBP (Callen and Benbow, 1995). Pell et al. (1999) argued that the Great Victoria Desert longitudinal dunes are older than previously thought, based on the apparent long-term stability of the dune field pattern and on a variety of other criteria including mineral grain provenance, dune morphology, contained secondary cements, grain ferruginous coatings and oxygen isotope ratios.

Since the advent of gold-in-calcrete sampling methodology in the late 1980s (Butt et al., 1991), dune-hosted calcretes and earthy carbonates have been a highly exploited sample medium, but their anomalous metal signatures have been difficult to interpret. On the premise that metal ions, released by weathering of primary mineralisation, can move into barren cover sediments, then it follows that a better knowledge of the time frame for dune formation and any associated palaeosol development will provide an accumulation rate for any externally sourced metal signatures (Fig. 3). Thus, assay results from dune-hosted calcretes can be properly compared with those from residually hosted equivalents, and therefore more informed interpretations drawn on what are background and anomalous metal values.

A prime question to answer is 'how long does it take to accumulate detectable externally sourced metal signatures in aeolian sediments that overlie mineralised crystalline basement?'

Dating methods

Conventional radiometric dating methods, such as radiocarbon, U-series, K–Ar and ^{10}Be are not applicable for the Great Victoria Desert sands because they are free of carbon, clay or other complex mineral components that can be dated. Moreover, the expected ages of the dunes are thought likely to be outside the ranges of conventional radiometric dating methods.

A number of alternative dating methods (stratigraphic, palaeomagnetic, amino-acid-racemisation and ^{18}O) and U-series have previously been applied to the stranded Pleistocene beach ridge dune sequence of southeastern South Australia (Sprigg, 1953; Idnurm and Cook, 1980; Schwebel, 1983; Belperio and Cann, 1990; Belperio, 1995). This well-studied dune sequence provided a chronologic 'test-bed' for applying two newer dating methods; namely, thermoluminescence (TL) dating and optical dating. Huntley et al. (1993a, b, 1996), along with Huntley and Prescott (2001), subsequently demonstrated that both methods can yield correct ages up to ~500 ka for such a dune system. Gardner et al. (1987) also established that TL dating of dunes in the Strzelecki Desert of northeastern South Australia yields good correlation with comparative radiocarbon dated materials. Gardner et al. concluded that their three TL dates beyond the limit of radiocarbon dating also have a high probability of being correct.

The Great Victoria Desert materials are suited to optical dating methods, particularly optically stimulated luminescence (OSL), and so OSL dating offers a newer tool to date that dune system.

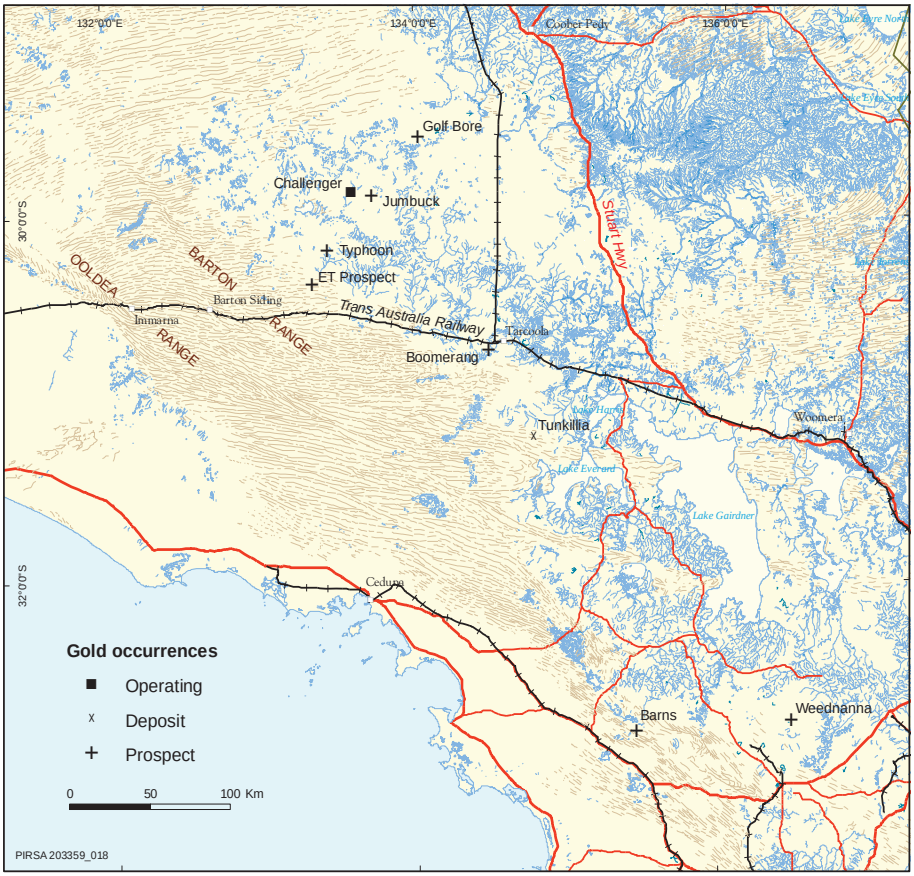

Figure 4 *Regional location plan of the Great Victoria Desert showing optical dating sample areas and known gold occurrences covered by Quaternary dunes.*

Interim summary results from this work were presented in Huntley et al. (1999) and Lintern (2004), based on the detailed optical dating technical report of Baril et al. (1999).

Project and locations

A pilot project was put together involving regolith and dating specialists from four institutions. Two sites, 75 km apart, along the Trans Australia Railway line between Tarcoola and the eastern edge of the Nullarbor Plain (Ooldea area) were selected (Fig. 4; Table 1):

- Site 1 near Immarna Siding — Quaternary dunes overlying the broader Palaeogene Ooldea Range barrier sands.
- Site 2 near Barton Siding — Quaternary dunes overlying the broader Neogene Barton Range back-barrier sands.

These longitudinal dunes are characterised by several phases of Pleistocene aeolian deposition where slightly fines-enriched cores visually appear to be considerably older than their associated near-surface equivalents (Rankin et al., 1996).

Immarna site

A dune cutting 13 km west of Immarna Siding on the Trans Australia Railway was selected (Fig. 5). Dune morphology profiles were obtained by dumpy levelling and differential GPS positioning (Fig. 6). Generally, this dune consists of loose to variably carbonate-cemented, fine, moderately well-sorted, subrounded to rounded quartz sand with minor felspar and trace opaques (Table 2; Figs 7, 8a). Typically the sand is pale pink or orange in colour and paler where significant secondary carbonate (calcrete) is present. The exposed dune core (4.5–>5.8 m below dune crest) consists of siliceous sand weakly bound by earthy carbonate, where pale pink blotches overprint the dominant orange colour (Figs 9–13). A significant calcrete zone lies between 4.0 and 4.5 m where nodules are abundant. A middle zone (2.5–4.0 m) displays broad cross-bedding, and carbonate rhizomorphs occur to at least 4 m below the crest. A loose surface horizon (<0.25 m) displays weak podsol development and contains numerous tree or shrub roots, some of which are relict and carbonised.

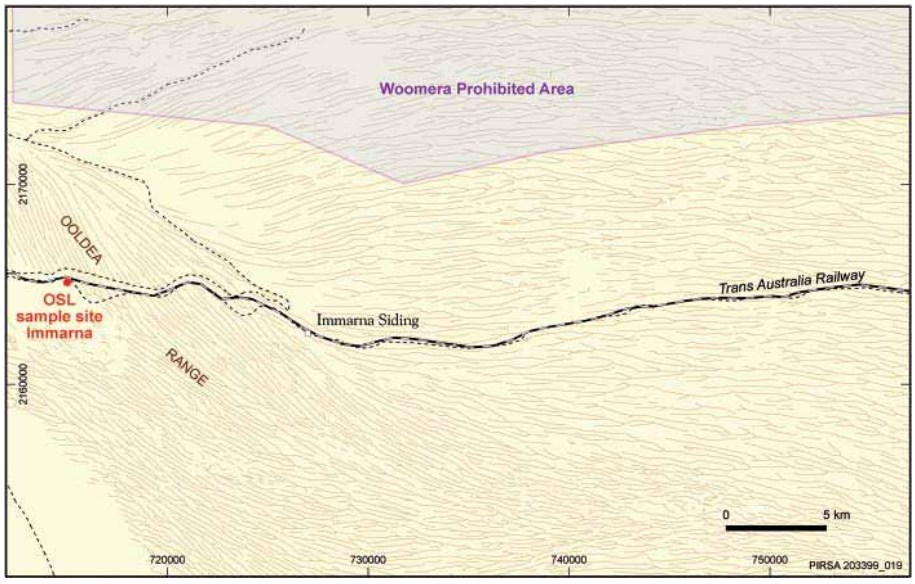

Figure 5 *Quaternary dunes and study site, Immarna Siding area, Ooldea Range.*

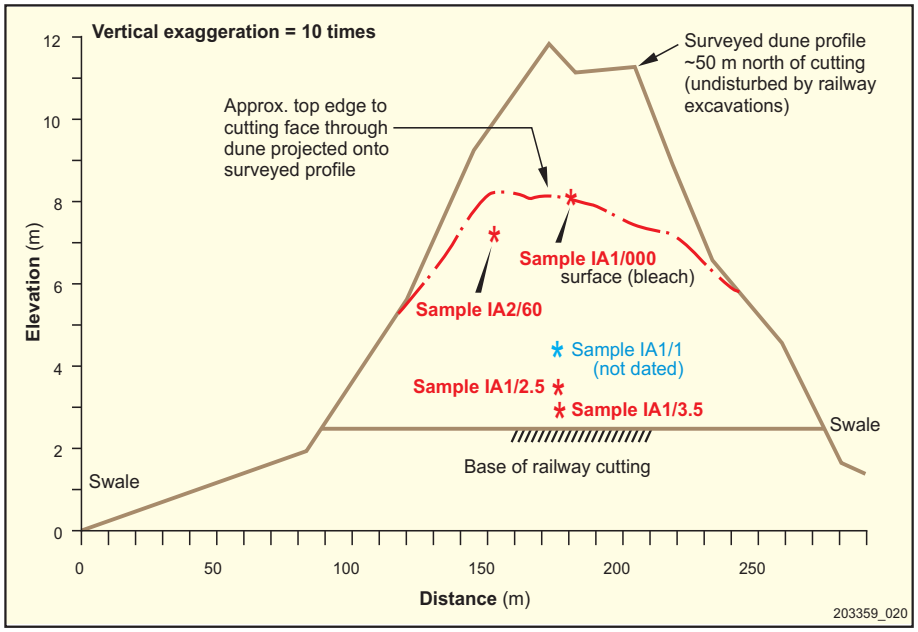

Figure 6 *Dune profile, Immarna site.*

Barton site

An abandoned railway loop 16 km east of Barton Siding on the Trans Australia Railway provided a second sampling location (Fig. 14). An old railway's borrow pit (20 x 4 x 2 m) provided access to the dune core on its northeastern flank; a smaller excavation ~0.8 m deep, 50 m to the north of the disused railway embankment, gave access to the swale (dune substrate) section (Figs 14, 15). Upper dune access was made via a manually dug pit near the dune crest (Fig. 16). This dune is similar in composition to the Immarna site, consisting of loose to variably carbonate-cemented, fine, very well-sorted to well-sorted, subrounded to rounded quartz sand with minor felspar and opaques (Table 2; Figs 7, 8b). Typically the sand is pink or orange in colour and is much paler where secondary carbonate (calcrete) occurs. The lowest zone has pedogenic carbonate rhizomorphs within a significantly enriched calcrete zone. Just above the trench top and on the dune's northern flank, modern deflation has exposed low-density pedogenic calcrete layers exhibiting micro-karstic solution surfaces and large layer-parallel calcrete rhizomorphs. Near the dune crest, an earthy calcrete zone is present. In summary, this dune has at least three discrete calcrete horizons from the core to its crest (Fig. 17).

Samples

Sand samples collected are described in Table 1; ~1 kg of each was obtained using a sand auger from the exposures available (Figs 11–12). In situ gamma ray spectrometry (Fig. 13) was used to obtain K, Th and U contents. Six of the original 12 samples collected were dated; a seventh sample, of dune substrate, proved to be beyond the dating range. Loose surface sand was taken at each of the sites investigated to demonstrate that the quartz and felspar mineral grains had been fully sun bleached, thereby eliminating any possible inherited radiation damage stored deeper within the dune. Major element assays for these samples (X-ray flourescence), are provided in Table 3.

Dating methodology

Sample preparation and measurement

For each sample, ~3 g of the 180–250 mm quartz grains were separated using sieving, hydrofluoric acid, and magnetic and density separation. Aliquots were prepared by evenly spreading 20–30 mg of the grains on 13 mm diameter aluminium planchets in which a few drops of 500 cSt silicone oil had previously been spread.

Luminescence was stimulated by 48 high-efficiency 2.4 eV (green) light-emitting diodes. The resulting luminescence was measured using a photomultiplier tube and photon-counting electronics, the 3.4 eV (ultraviolet) quartz emission band being selected using suitable optical filters.

In order to determine the past radiation dose (*senso stricto* the equivalent dose), various aliquots were given different radiation doses using a ^{60}Co gamma (γ) ray source, heated at 160 °C for 16 h, and the OSL measured. The intensity was plotted against laboratory radiation dose, and the past dose found by extrapolation to the dose axis, with a small correction for an undesired side effect of the heating.

This procedure was found to be suitable for only two samples (BN3/1.2 and IA2/60). For the others, the dose response was significantly non-linear, because they were older, and a 'regeneration' method was used (Prescott et al., 1993). Here, some aliquots were given radiation doses, while others were first given light exposures and then radiation doses. The light exposure was sufficient such that, after applying it to

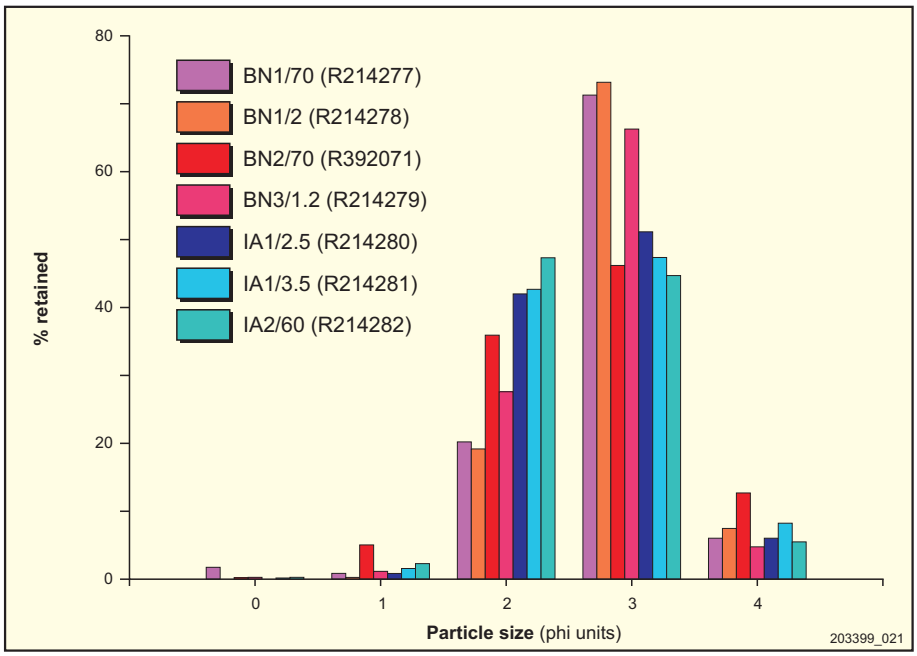

Figure 7 *Sand-sized grain size distribution for the subsurface samples dated in the Immarna and Barton areas. Samples had carbonate removed prior to analysis.*

Figure 8 (a) *Sample IA1/3.5 (R214281) showing rounded to subrounded quartz grains with a dusting of carbonate and clay.* ***(b)*** *Sample BN2/70 (R392071) showing rounded to subrounded iron-stained quartz grains with a dusting of carbonate and clay. Fields of view 0.9 x 2.25 mm. (Photos 403354, 403355)*

Table 1 *Sample and materials data, Immarna and Barton sites*

Sample	PIRSA number	Zone	Easting	Northing	Depth below surface (m)	Munsell colour (dry)	Munsell colour (wet)	Comments
Immarna								
IA1/2.5	R214280	53J	214144	6625063	2.5	5YR 8/4	5YR 7/5	Loose running sand, damp
IA1/3.5	R214281	53J	214144	6625063	3.5	5YR 8/4	5YR 7/5	Loose running sand, damp
IA1/000	—	53J	214144	6625063	0.0	—	—	Loose running sand, dry
IA2/60	R214282	53J	214115	6625071	0.6	5YR 8/6	5YR 7/6	Loose running sand, dry
Barton								
BN1/70	R214277	53J	290334	6616407	0.7	5YR 8/6	5YR 7/5	Loose running sand, dry
BN1/2	R214278	53J	290334	6616407	2.0	5YR 8/4	5YR 7/5	Loose running sand, damp
BN1/000	—	53J	290334	6616407	0.0	—	—	Loose running sand, dry
BN2/70	R392071	53J	290375	6616447	0.7	5YR 7/8	5YR 5.5/8	Fines-rich sand, dry
BN3/1.2	R214279	53J	290329	6616394	1.2	5YR 8/6	5YR 7/8	Loose running sand, damp
BN3/000	—	53J	290329	6616394	0.0	—	—	Loose running sand, dry

Notes: Samples BN1/000, BN3/000 and IA1/000 are all surface sand collected for solar bleach testing. All GPS data was collected in AGD66 coordinates.

Table 2 *Sedimentological characteristics of dated samples*

Sample	PIRSA number	Mean j	Median j	Standard deviation j	Skewness	Kurtosis
IA1/2.5	R214280	Fine sand	Fine sand	Moderately well sorted	Near symmetrical	Mesokurtic
IA1/3.5	R214281	Fine sand	Fine sand	Moderately well sorted	–ve skewed	Mesokurtic
IA2/60	R214282	Fine sand	Fine sand	Moderately well sorted	–ve skewed	Mesokurtic
BN1/70	R214277	Fine sand	Fine sand	Well sorted	Near symmetrical	Leprokurtic
BN1/2	R214278	Fine sand	Fine sand	Very well sorted	Near symmetrical	Mesokurtic
BN2/70	R392071	Fine sand	Fine sand	Moderately well sorted	Near symmetrical	Mesokurtic
BN3/1.2	R214279	Fine sand	Fine sand	Well sorted	Near symmetrical	Mesokurtic

Note: TD class = x 129

Table 3 *Major element analyses (%) by XRF of dated samples*

Sample	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	SO_3	Total	$CaCO_3$	New total
IA1/2.5	93.60	1.05	0.70	0.01	0.28	1.82	0.02	0.121	0.16	0.01	<0.00	97.75	3.25	99.18
IA1/3.5	88.15	1.13	0.71	0.01	0.55	4.63	0.04	0.148	0.17	0.01	<0.00	95.44	8.27	99.08
IA2/60	94.09	1.00	0.68	0.01	0.21	1.69	0.01	0.100	0.16	0.01	0.01	97.96	3.02	99.23
BN1/70	89.12	1.51	0.86	0.01	0.66	3.36	<0.01	0.116	0.21	0.01	<0.01	95.85	6.00	98.49
BN1/2	90.84	1.46	0.80	0.01	0.51	2.74	0.04	0.138	0.20	0.01	0.01	96.76	4.89	98.91
BN2/70	83.28	2.72	1.34	0.01	0.56	5.56	0.01	0.235	0.25	0.02	0.01	93.98	9.93	98.35
BN3/1.2	92.17	1.43	0.83	0.01	0.18	2.32	<0.01	0.082	0.18	0.01	<0.01	97.21	4.14	99.03

Note: All samples were dried at 110 °C to remove adsorbed water, but were not pre-ignited. To improve the assay values, CaO data have been recalculated to $CaCO_3$ (second to last right hand column) and new totals displayed in the last column.

Table 4 *Equivalent dose, water, K, U and Th contents, radiation dose rate and optical age of dated samples*

Sample	Equivalent dose (Gy)[a]	Water content (Δ)[b]	In situ gamma ray spectroscopy[c]			Dose rate (Gy ka^{-1} ± 0.02)	Age (ka)
			K (%)	U ($\mu g*g^{-1}$)	Th ($\mu g*g^{-1}$)		
IA1/2.5	86.3 ± 5.1	0.027	0.108 ± 0.007	0.33 ± 0.06	1.54 ± 0.11	0.46	188 ± 14
IA1/3.5	104.6 ± 6.2	0.021	0.128 ± 0.007	0.39 ± 0.06	1.74 ± 0.11	0.49	215 ± 15
IA2/60	10 ± 1.5	0.023	0.087 ± 0.007	0.33 ± 0.06	1.36 ± 0.10	0.46	22 ± 3
BN1/70	52.6 ± 3.5	0.023	0.090 ± 0.007	0.34 ± 0.06	1.73 ± 0.11	0.50	105 ± 8
BN1/2	93.3 ± 5.9	0.017	0.115 ± 0.007	0.34 ± 0.06	1.60 ± 0.11	0.47	197 ± 14
BN2/70	>125	0.022	0.202 ± 0.009	0.63 ± 0.07	2.60 ± 0.13	0.50	>250
BN3/1.2	33 ± 3	0.025	0.074 ± 0.007	0.39 ± 0.06	1.49 ± 0.10	0.46	71 ± 8

a Gray (Gy), the SI unit of radiation dose, is defined as one joule per kilogram of absorbed energy. In the natural environment, the dose rate is ~1 Gy/ka.
b Expressed as Δ = water mass divided by dry mass. c Corrected to dry values.
Note: The luminescence measurements on BN2/70 (the substrate sample) showed it to be older than could be determined by the method.

the sample, any OSL was negligible. Both sets of aliquots were then heated and measured. The luminescence versus dose data for both sets were then superimposed by shifting one set along the dose axis, the best-fit shift being determined by a maximum likelihood routine. This shift was taken to be the past radiation dose; an example is shown in Figure 18. Details are provided in Prescott et al. (1993). The equivalent doses so determined are shown in Table 4.

Dosimetry

Radiation dose rates were calculated from measured concentrations of radioisotopes, the cosmic-ray intensity and water contents. The relevant radioisotopes are ^{40}K and those in the decay chains of ^{238}U, ^{235}U and ^{232}Th. Potassium contents were determined by both XRF and in situ gamma ray spectrometry, and were found to be in good agreement. Uranium and Th contents were determined by delayed-neutron analysis, neutron-activation analysis, in situ spectroscopy and thick-source alpha counting. These different techniques measure activities of different parts of the Uranium and Th decay chains, thus differences in results can be attributed to a lack of secular equilibrium in the chains, which is important to the calculation of the dose rates. There were no differences of any consequence in the results from the different methods, thus no allowance for disequilibrium was made. Table 4 displays the measured water content and the K, U and Th contents determined by in situ gamma ray spectroscopy.

Radiation dose rates were calculated, making use of all the analytical data, using the dose conversion factors given by Nambi and Aitken (1986) as updated by Adamiec and Aitken (1999). The beta attenuation factor was calculated using the figures of Mejdahl (1979). Cosmic-ray dose rates were calculated using the prescription of Prescott and Hutton (1994). Total dose rates are shown in Table 4.

Ages

Optical ages were determined by dividing the equivalent doses by the dose rates, and are shown in Table 4. Initially it was anticipated that all the samples would be post-glacial, i.e. <20 000 y old. Preliminary experiments however, showed this not the case and led to the use of a regeneration method for determining past radiation doses, as the dose response curves show that the older samples were

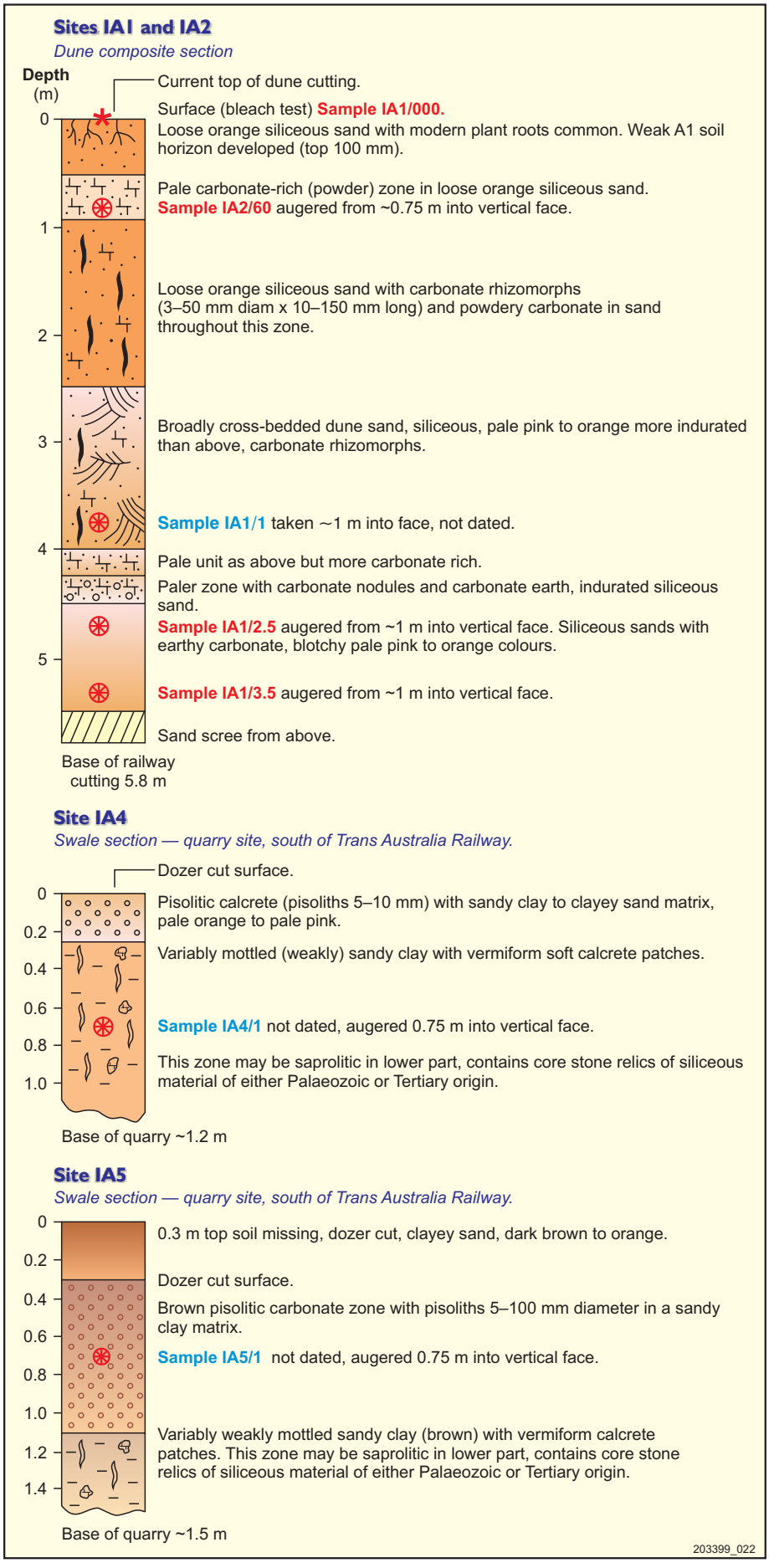

Figure 9 *Site logs, Immarna.*

Figure 10 *Easterly view of the Immarna area rail cutting, north side, and main optical dating sampling location. Scale staff 3 m long.* (Photo 403342)

Figure 11 *Two of three horizontal optical dating sample holes in the Immarna rail cutting. Hole 3, the lowest, is hidden by the excavation spoil pile. Scale staff 3 m long.* (Photo 403350)

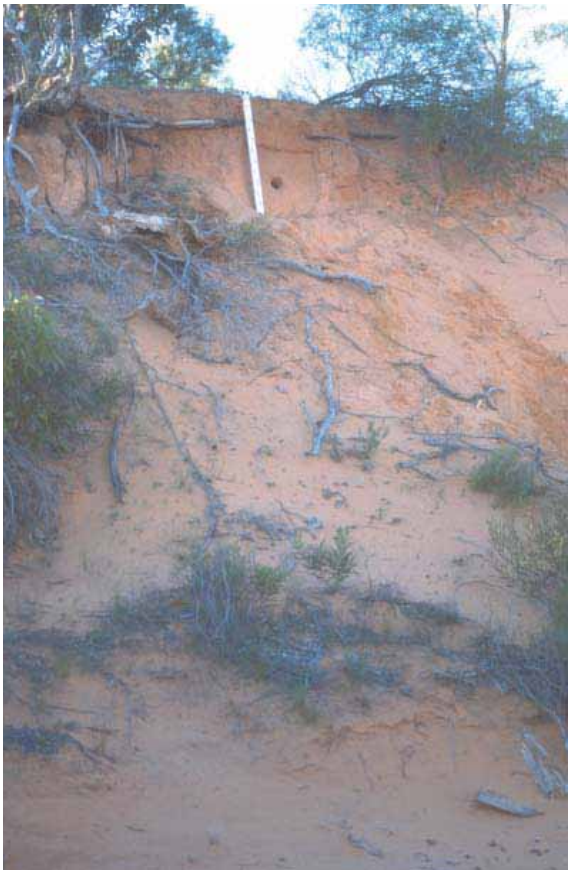

Figure 12 *Upper horizontal optical sample hole in the Immarna rail cutting, near the dune crest. Scale staff 1.2 m long.* (Photo 403351)

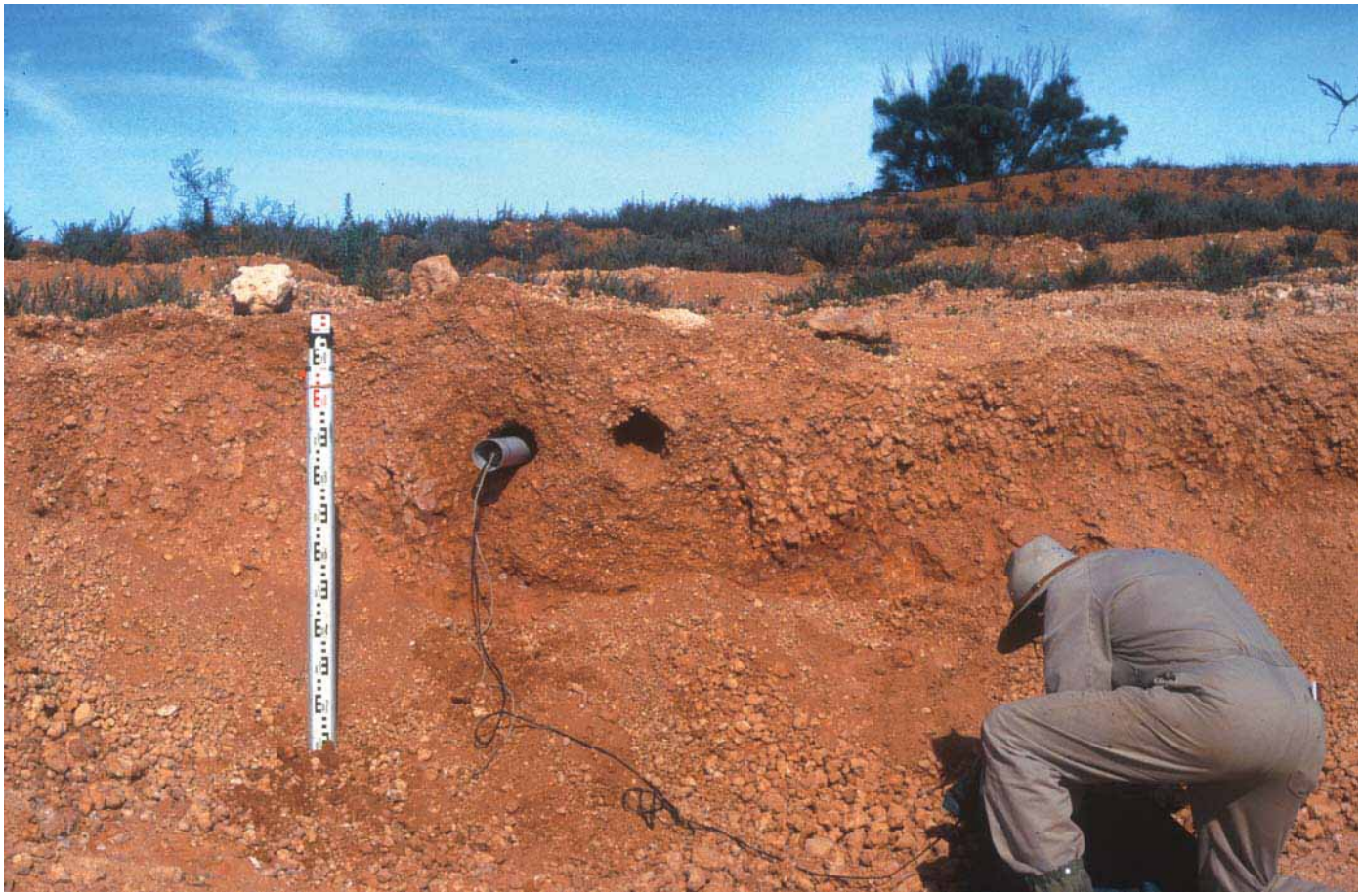

Figure 13 *Optical dating dosimetry data collection in a swale exposure near Immarna rail cutting. The scintillometer is in the temporary plastic casing and is being monitored by the attached gamma ray count data logger. Scale staff 1.2 m long.* (Photo 403352)

approaching saturation, such as shown in Figure 18. This was a challenge. Although we have established that TL dating can be reliable for past doses up to ~200 Gy (Huntley et al. 1993a, b; Huntley and Prescott, 2001), the reliability of the optical dating method used here for quartz has not been demonstrated for past doses in excess of 60 Gy, and when calculating the ages we have assumed its validity up to 100 Gy. This point is important because the trapped electrons made use of in TL and optical dating are different. Because we know that in felspars the relevant trapped electrons are not stable, an allowance for this has to be made. A method for testing the stability of the trapped electrons is to determine whether or not 'old' quartz, that is expected to be in saturation, is indeed in saturation. We made this test using four samples from elsewhere in southern Australia. The results showed that the luminescence intensity of these samples was typically at 96% of the saturation intensity and because of the scatter we cannot be sure that they are not at 100%. This test would be better had it been done on samples from the Ooldea–Barton region, but such

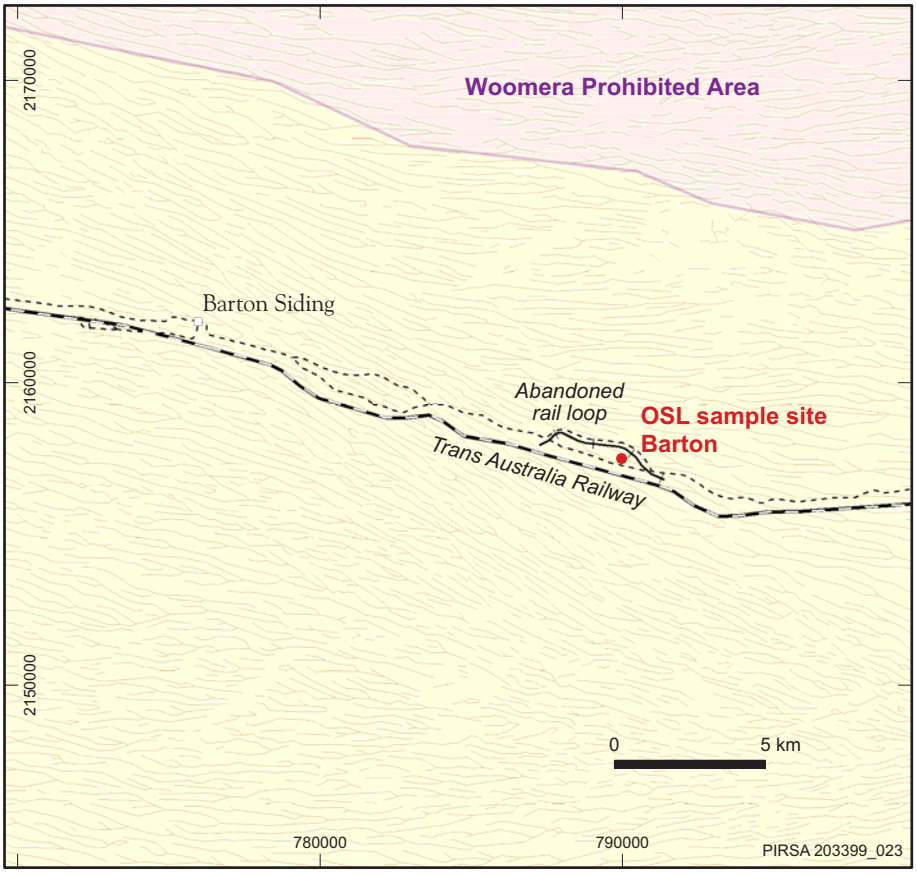

Figure 14 *Quaternary dunes and study site, Barton Siding area, Barton Range.*

Figure 15 *Optical dating horizontal sample hole (BN2/70) in a clayey sand swale exposure near the abandoned Barton Siding rail loop and north of the sampled dune. Book scale 0.2 m long. (Photo 403353)*

samples were not available. We can only say it is likely that quartz from different regions behaves similarly, and on this assumption we conclude that the ages cited may be slightly older than those shown in Table 4. If the 96% value is valid, the ages should be increased by 4% for BN1/70, and 7% for the others. The significance of this is that although the ages of samples BN1/2, IA1/2.5 and IA1/3.5 correspond to ^{18}O stage 7, one should not attempt to allocate them to any particular substages because of the possible errors involved.

Discussion

TL dating reported by Gardner et al. (1987) of desert and arid area dunes in the Strzelecki Desert and Murray Mallee of South Australia yielded the following TL age ranges: ~4–15, ~20–27, ~31–35 and ~48 ka. In addition, there was an older set of three dates from their 'Lark Pit' site in the Strzelecki Desert where TL ages ranged over ~89–99, ~167 and ~229–243 ka, all well beyond the limit of the radiocarbon date comparisons they had employed, but with a high probability of being correct.

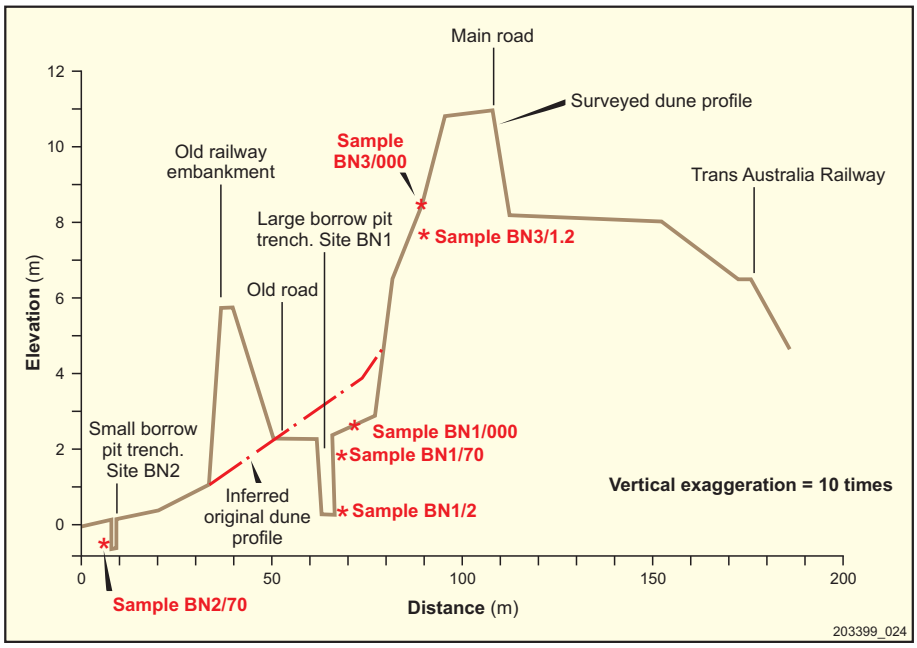

Figure 16 *Dune profile, Barton site.*

Optical dating of aeolian dune sands from a number of Australian deserts have been recently reported: aeolian dunes near Birdsville, Queensland (~36 ka; Twidale et al., 2001); dunes of the Strzelecki Desert near Moomba and Merty Merty within South Australia (~65 ka; Lomax et al., 2003); and there are 20 age estimates from sites in Victoria, Western Australia and New South Wales yielding three or possibly four age clusters centring on ~21, ~36, ?~43 and ~68 ka (Rhodes et al., 2004). Replotting by Rhodes et al. of the dating results from Nanson et al. (1992), along with other data sets for a total of 54 aeolian samples from the Strzelecki and Tirari Deserts, confirm those three or possibly four dune-building phases prior to 70 ka. Luminescence-dated longitudinal dunes from Australia's southern arid zone are also graphically presented in Hesse et al. (2004), where seven samples from 11 sites yielded dune-building phases within the following age ranges: ~115–135, ~145–155, ~185–205 and ~225–235 ka.

The dune ages reported here are regarded as unexpectedly old and indicate a long-term stability of the eastern Great Victoria Desert dune field, a conclusion that has also been drawn by Pell et al. (1999) on different grounds. Dune core ages are also significantly older than for the majority of those reported from deserts of eastern and northern South Australia by Gardner et al. (1987), and all of those reported by Nanson et al. (1992), Twidale et al. (2001), Lomax et al. (2003) and Rhodes et al. (2004). However, they do correspond with the older dune-building age clusters reported by Gardner et al. (1987) and Hesse et al. (2004). We reiterate that although three of our dune core samples (BN1/2, IA1/2.5, IA1/3.5) do correspond to ^{18}O stage 7, one should not attempt to allocate them to any particular ^{18}O substage because of the possible errors involved. Moreover, establishing a reliable and meaningful ^{18}O correlation directly from terrigenously sourced very siliceous sands would be highly unlikely (Belperio, 1995). Samples BN3/1.2 (71 ± 8 ka) and IA2/60 (22 ± 3 ka) do correspond to two of the three dune-building phases presented by Rhodes et al. (2004), while sample BN1/70 (105 ± 8 ka) may belong to another dune-building phase alluded to through dates in Gardner et al. (1987), English et al. (2001), and as graphically demonstrated by Hesse et al. (2004, p. 96, fig. 9).

It is probable that some degree of dune reactivation within the Great Victoria Desert did sporadically occur during the later dune-building phases recognised elsewhere in Australia (Hesse et al., 2004; Rhodes et al., 2004), and as suggested by the limited younger ages reported herein. However, generally over that region, dune loci and overall morphology seem to have remained substantially unchanged during any later sand reactivation.

Further optical dating in conjunction with TL dating along an extended W–E transect (parallel to dune long axes) is required to demonstrate whether there are more definable dune-building phases and if there is a measurable west to east diachronous character to this desert's dune system, as implied by Wasson (1989).

Establishing the age of the dunes covering potentially mineral-prospective ground is significant in the context of regolith geochemistry, especially regarding the sampling of calcrete for anomalous gold and base metal signatures that may have been geochemically transported into the weathered in situ and sedimentary regolith. Dune-hosted calcrete must be younger than the dune and inter-dune sand within which it develops. Since much of the terrain over the Gawler Craton is unevenly covered with Great Victoria Desert dunes, it is important to know whether the dunes have been in position long enough for their secondary calcrete to acquire a gold or base metal signature, and whether sampling those materials is likely to prove advantageous. Work in progress from other areas of the Gawler Craton where sand dunes occur indicate that anomalous gold occurs within some dune-hosted calcretes (Lintern, 2004; Lintern et al., 2006). Samples collected more recently from quartz-rich sand dunes over the Barns and ET gold prospects (Fig. 4), where dune-hosted calcrete assays anomalous in gold have been optically dated and reported by Lintern and Rhodes (2005).

Dating summary

Optical dating was applied to dunes in the Ooldea and Barton regions of the eastern Great Victoria Desert of western South Australia. Quartz grains were extracted from those dunes, 2.4 eV (green light) excitation was used and the 3.4 eV (ultraviolet) luminescence emission measured. The measured age for the dune core at the Immarna site spans a time

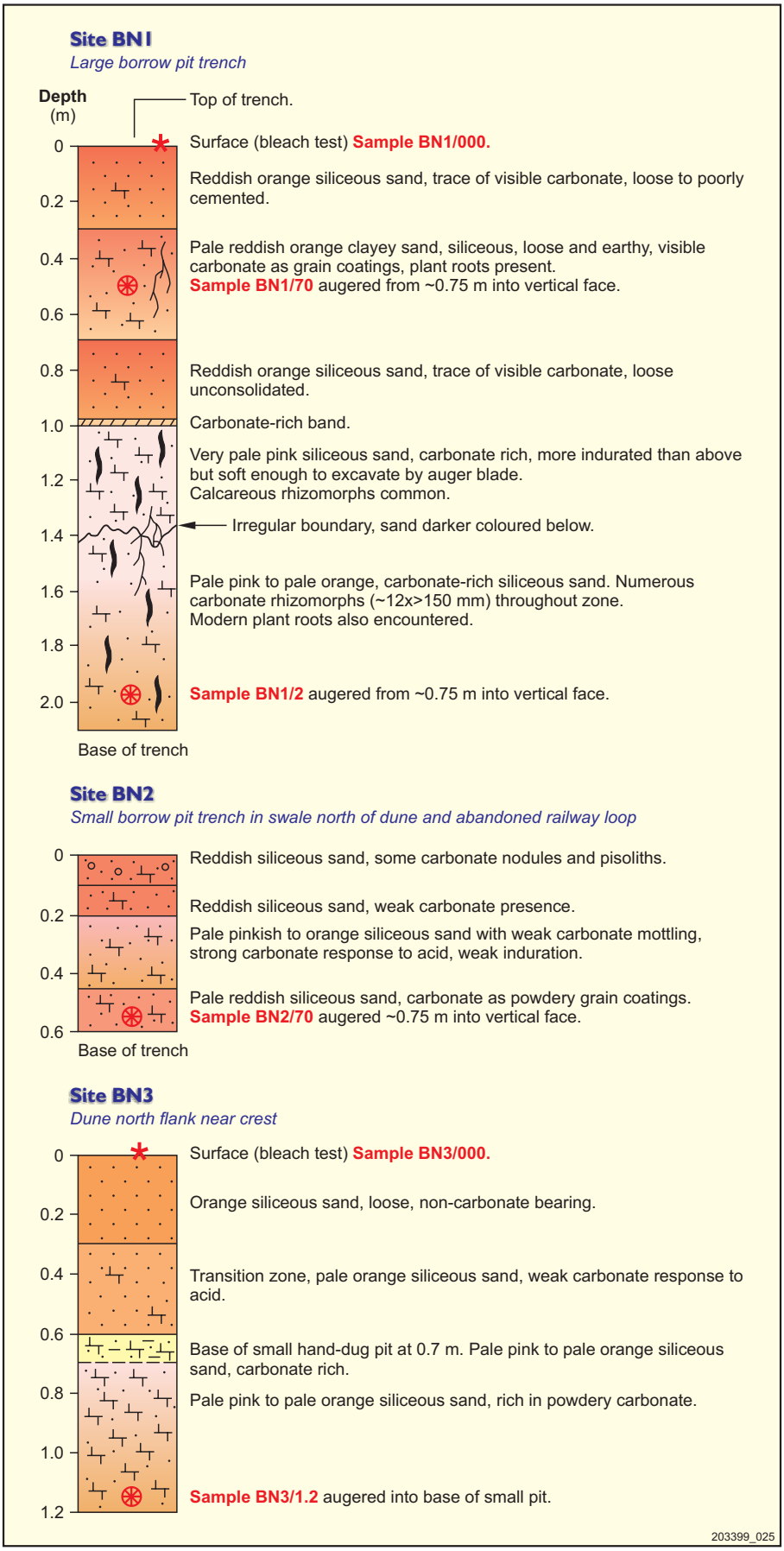

Figure 17 *Site logs, Barton.*

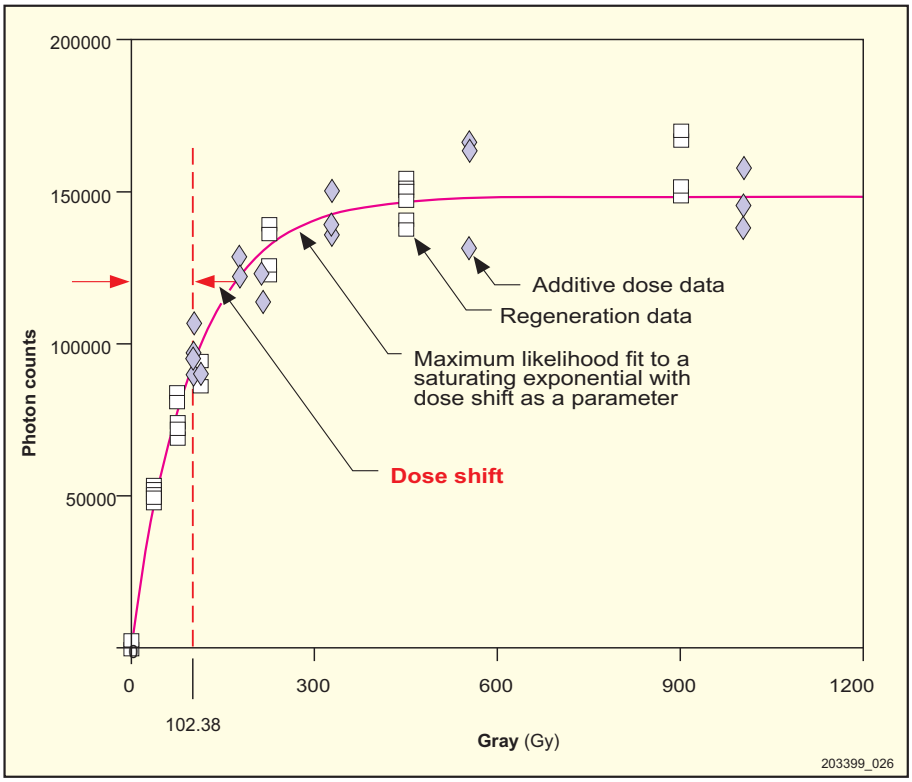

Figure 18 *Fitted additive–regeneration curve for sample IA1/3.5 (Immarna). The estimated dose (102.38 Gy) is shown by the vertical red dashed line. This sample is approaching saturation.*

range of 215 ± 15 to 188 ± 14 ka and, similarly for the Barton site, the age range spans 197 ± 14 to 105 ± 8 ka. These fall within the oldest two Australian dune-building phases presented by Hesse et al. (2004; ~185–205 and ~225–235 ka) and therefore rank as amongst the oldest dunes dated in South Australia. One dune substrate proved to be beyond the time range that can be dated by the OSL method. TL dating can date quartz up to 500 ka (Huntley et al., 1993a, b; Huntley and Prescott, 2001) and so our ancient substrate material may be one of those rare cases where TL dating may be more suited than optical dating.

A maximum time frame for any dune-hosted, but externally sourced, metal signatures detected for sands of the Great Victoria Desert longitudinal dunes is therefore established at <220 ka.

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What is optical dating?

On exposure to natural radiation from the environment, many crystals, of which quartz is an example, store a proportion of the absorbed energy in the crystal lattice. When the crystal is exposed to green light, some of this stored energy is released and some of that is emitted as ultraviolet light: this light is referred to as optically stimulated luminescence (OSL).

The intensity of this light is a measure of the energy that had been stored since the sample was last exposed to sunlight. The process serves as a clock which is set to zero by sunlight exposure and which runs at a rate determined by the rate of absorption of energy. The technique is referred to as optical dating.

This process can be used to date wind-borne and water-borne sediments that have been exposed to sunlight during transport.

Optical dating is now useful for times from tens of years to 300 ka, and is beginning to show promise for times approaching 1 Ma.

How does dating work?

The actual laboratory process of dating involves a four-step measurement:

1. suitable minerals (i.e. quartz) are extracted from a sample by chemical and/or physical means
2. energy trapped by crystal impurities as a result of environmental ionising radiation (from K, Th, U) is measured by recording the light emitted when the sample is stimulated by light of a different wavelength (OSL)
3. the sensitivity to ionising radiation is determined with a calibrated radiation source
4. the rate of delivery of energy (dose rate) from radioactivity in the sample and environment is found.

An age then follows from the age equation:

$$\text{Age (y)} = \frac{\text{Luminescence output}}{\text{Luminescence per unit dose} \times \text{dose per year}}$$