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Gold dispersion in transported cover sequences especially in chemical (palaeoredox front) and physical (unconformity) interfaces linked to the landscape history of Western Australia

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Introduction

Transported cover is exotic or redistributed material of continental origin that blankets weathered and fresh bedrock, effectively obscuring bedrock-hosted mineralisation in many prospective areas. It includes unconsolidated to consolidated glacial, fluvio-glacial, colluvial-alluvial, lacustrine and estuarine sediments, evaporites and aeolian materials and several may occur in the sequence at a given site (Anand & Paine, 2002). In this paper, the term transported cover excludes marine, lithified sequences in sedimentary basins. Surficial sampling techniques have limited application in areas of deep transported cover. Many investigations have sought evidence for active dispersion through transported cover. In various locations, targeted sampling media such as termite mounds (e.g., Petts *et al*. 2009; Stewart *et al*. 2012; Stewart & Anand 2014), pedogenic carbonates (Lintern 2015), vegetation (e.g., Hill, 2004; Hulme & Hill 2005; Anand *et al*. 2007; Reid *et al*. 2008; Lintern *et al*. 2013a; Anand *et al*. 2016; Noble *et al*. 2017) have been shown to give a response through 2 to 20 m and rarely 30 m of transported cover in certain environments. Deep drilling through this cover to sample basement rocks is costly, yet the transported cover itself may provide an opportunity for exploration, due to geochemical dispersion from mineralisation into cover. If transported cover is to be a useful sample medium, indicator elements need to be dispersed into the cover during deposition and/or by post-depositional weathering and diagenesis. As older transported cover is more likely to contain elements that have been chemically dispersed from concealed mineralisation, the relative timing of continental sedimentation and the subsequent weathering events are important to understand for successful exploration. Older transported cover deposited during the Permian and Eocene-Miocene will have been subjected to more post-depositional alteration (and therefore trace element dispersion) than younger Quaternary transported cover such as recent colluvium and alluvium (Anand *et al*. 1993; Radford & Burton 1999; Butt *et al*. 2005; Hore & Hill 2009; Anand & Robertson 2012; Anand 2016; Salama *et al*. 2016a; Salama *et al*. 2018a,b; Baudet *et al*. 2018). In this paper, we will show how understanding metal dispersion in three transported cover settings (Permian, Eocene-Miocene and Quaternary) in Western Australia (Yilgarn Craton, Albany Fraser Orogen, Paterson Orogen) can be used to find buried gold deposits.

As it is impractical to sample the entire transported cover sequence, selective sampling is required. There are two types of interfaces that may be targeted to discover mineralisation (physical and chemical; Fig. 1), both of which are abundant and can be sampled from near-surface or by shallow drilling.

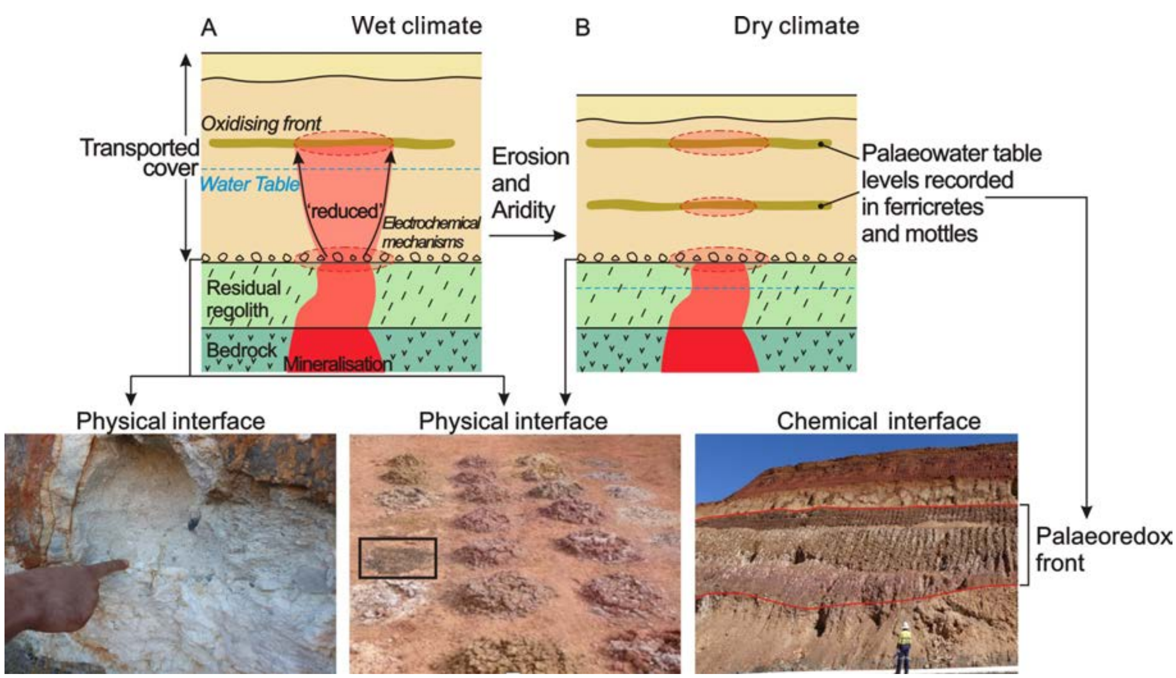

Figure 1. *Diagram and photos showing two types of interfaces (physical and chemical) in situ and in drill cuttings. Metal transfer in the regolith is driven by the influence of climate that disperses metals into chemical interfaces (modified after Anand et al. 2016). (A) A high water table within the transported cover, during an initial wet climate would allow electrochemical metal transfer to and adsorption onto redox materials (nodules, pisoliths, mottles). (B) Subsequent onset of aridity lowers the water table but the original anomalous zones remain.*

continued on page 5

EXPLORE

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EXPLORE Publication Schedule

Quarterly newsletters are published in March, June, September, December

Deadlines for submission of articles or advertisements:
March newsletter: January 15
June newsletter: April 15
September newsletter: July 15
December newsletter: October 15

Manuscripts should be double-spaced and submitted in digital format using Microsoft® WORD. Articles should be between 2000 and 3000 words. Do not embed figures or tables in the text file.

Figures and/or photos (colour or black and white) should be submitted as separate .eps files. Alternate file formats include high resolution (2400 dpi or higher) tiff, jpeg or PDF files.

Tables should be submitted as separate digital files in Microsoft® EXCEL format.

All scientific/technical articles will be reviewed. All contributions may be edited for clarity or brevity.

Formats for headings, abbreviations, scientific notations, references and figures must follow the *Guide to Authors for Geochemistry: Exploration, Environment, Analysis* (GEEA) that are posted on the GEEA website at: https://www.geolsoc.org.uk/geea-authorinfo

An abstract of about 250 words must also be submitted that summarizes the content of their article. This abstract will be published in the journal ELEMENTS on the 'AAG News' page.

Submissions should be sent to the Editor of **EXPLORE**:
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TABLE OF CONTENTS

ADVERTISERS

Notes from the Editor

Welcome to the second **EXPLORE** issue of 2019. This issue features an article that describes gold dispersion in transported cover sequences of Western Australia and was written by Ravi Anand and Walid Salama. Also include in this issue are two obituaries, one for Gerry Govett and one for Tom Lane.

EXPLORE thanks all those who contributed to the writing and/or editing of this issue, listed in alphabetical order: Steve Amor, Dennis Arne, Al Arsenault, John Carranza, David Cohen, Steve Cook, Benedetto De Vivo, Tomas Grijalva, David Leng, Leslie Logan, Tom Meuzelaar, and Paul Morris and Walid Salama.

Beth McClenaghan
Editor

2019 AAG Dues Reminder

To renew your 2019 AAG Membership, please go to the AAG website at www.appliedgeochemists.org/ and click on "Membership" in the right side of the menu, then click on "Renew Membership".
If you have any questions about your membership or receipts please contact the AAG Business Office at office@appliedgeochemists.org .

President's Message

As I write this message in late April, spring is in the air in the northern hemisphere, and geochemists and geologists are preparing once again for summer field work. I have several items to mention before our members depart for their exploration and research programs.

In my previous message, I touched on the importance of education of the next generation of applied geochemists in light of the aging demographics of our profession. As part of our ongoing commitment to geochemical education and continued learning, the AAG is pleased to have been a sponsor of two recent scientific meetings and seminars in the southern hemisphere. First, the AAG was a co-sponsor of the PACRIM 2019 (Mineral Systems of the Pacific Rim) congress in Auckland, New Zealand, which was held April 3-5. More specifically, the AAG sponsored an exploration geochemistry session (April 3) as well as a day-long exploration geochemistry workshop at the PACRIM conference. The Association supported the travel of three members – Juan Carlos Oronez Calderon (Hudbay Minerals), Steve Piercey (Memorial University of Newfoundland) and Dennis Arne (Telemark Geosciences) - to Auckland to variously give keynote presentations on exploration geochemistry, chair sessions and run the geochemistry workshop. The theme of the workshop was 'Exploration Geochemistry: Applying Fundamentals in the Field', and was presented by David Cohen (University of New South Wales), Dennis Arne and Steve Piercey. There was a mixture of presentations and exercises for the 20 delegates in attendance. Juan Carlos Oronez Calderon also contributed to a short course on machine learning and data analytics after the main conference.

Secondly, the AAG sponsored the recent Australian Institute of Geoscientists (AIG) applied mineralogy in exploration seminar in Perth, Western Australia on April 9. This day-long seminar was part of a wider 3-day exploration geochemistry workshop and seminar session, and was the second seminar in the 'Exploration Geochemistry Series' hosted by the WA branch of the AIG. It was organized by Helen Waldron (Xenocryst Geoscience Consulting), and focused on the use of mineral methods in exploration including spectral techniques, automated mineralogy and SEM-based, pXRF and indicator mineral methods. A total of 72 people were in attendance, representing a broad spectrum of the Australian exploration community.

Looking ahead, I encourage all applied geochemists to mark their 2020 calendars for next year's 29th IAGS in Viña del Mar, Chile, in November 2020, which we will co-sponsor with the Geological Society of Chile (SGCH). The International Applied Geochemistry Symposium is the flagship conference of our Association, and is the only scientific meeting devoted to the advancement of applied geochemistry in both mineral exploration and environmental studies. Meeting chair Brian Townley (University of Chile) is putting together a comprehensive program of talks, workshops and field trips for a geologically spectacular part of the world. The website should be up and the First Circular available for distribution sometime in June. The 29th IAGS in Chile will be the latest in a long series of such applied geochemistry symposia going back several decades, the abstracts for which are all now available in pdf form on the AAG website.

This is an appropriate point to say a few words about the work of our Regional Councilors. They play an important role in promoting the advancement of geochemistry throughout the world, as well as relaying news and the concerns of geochemists in those regions back to the attention of AAG Council. Their regional reports are available to all members on the AAG website. I am very pleased to announce that AAG Council has approved the appointment, for the first time, of a new regional councilor for Mexico, Tomas Israel Grijalva Rodriguez of the Mexican Geological Survey (SGM). We welcome Tomas to Council, and look forward to working with him in his efforts to promote the use of geochemistry in Mexico.

EXPLORE newsletter is always looking for interesting new features and ideas for the benefit and interest of AAG members and, as I have mentioned in earlier messages, the Association is nearing the 50th anniversary of its founding next year. In consultation with Editor Beth McClenaghan, I am putting out a call for interesting historical photos of geochemists in action over the years, doing interesting things in interesting places. The objective would be for such a photo to be a regular feature of **EXPLORE**. Please email your photos, suitably described, to Beth at: beth.mcclenaghan@canada.ca

As a final note, last month we learned of the passing of Dr. Vic Levson, long-time surficial geologist at the British Columbia Geological Survey in western Canada, also Adjunct Professor at the University of Victoria and, more recently, a consulting geologist. Vic's interests in glacial ice flow reconstructions, till geochemistry, and placer gold deposit sedimentology have been critical to surficial geochemical research and exploration in western Canada over the past few decades. He was an exceptional scientist and a truly decent man, and I had the privilege of working on many field projects with him. We will provide further discussion of his life and career in a later issue of **EXPLORE**.

Stephen Cook, *President*

Gold dispersion in transported cover sequences especially in… *continued from page 1*

Physical interface sampling is based on the possibility of dispersion at or close to an unconformity between the transported cover and the underlying rock by (i) mechanical dispersion of remnants of weathering, such as ferruginous duricrust, mineral grains, lithic and gossan fragments, and (ii) hydromorphic dispersion after deposition of the transported cover by groundwater percolating through the coarse, basal cover along the unconformity itself and/or the upper residual material (Anand *et al*. 1993; Robertson *et al*. 1996; Anand 2000; Robertson *et al*. 2001; Butt *et al*. 2005; Anand & Robertson 2012). These mechanisms result in lateral dispersions at the base of the cover, without upward dispersion. The base of the cover can be a simple, sharp, erosive unconformity or a complex mixture of saprolite and transported cover, a metre or more thick, possibly including a buried palaeosol. The extent of lateral dispersion is governed by the topography of the unconformity.

Chemical interface (palaeoredox fronts) sampling is based on hydromorphic dispersion into weathering products such as Fe and Mn oxides formed in transported cover when the water tables were higher. Although much of Australia is now semi-arid to arid, old transported cover (Permian; Eocene-Miocene) will have a long history of weathering under very different climates (discussed later). Transported cover across Australia can date back to the Permo-Carboniferous (Veevers 2000; Eyles & de Broekert 2001; Pillans 2005). Depending upon past climate and landscape positions, the water table could have been near the surface with connected saturation reaching from buried ore to the top of the water table (Fig. 1A). The development of a water table within transported cover sets up a redox gradient with oxidising conditions prevailing at and above the water table and reducing conditions below (Anand *et al*. 2016). The water table-associated Eh difference causes reduced ions (Fe^{2+}, Mn^{2+}) released from the weathering front to migrate upwards and oxidise at or near the water table (oxidation front), resulting in ferrolysis with the generation of acidic conditions at the oxidation front (Mann 1983). Thus, high water tables in wet climates are likely to electrochemically transfer metals into the cover across an Eh gradient (Fig. 1A; Anand *et al*. 2016). Anomalous zones are likely to be in water table-associated redox zones such as ferruginous nodules, pisoliths and mottles. These can be loose or cemented into a ferricrete. A shift to a drier climate coupled with erosion, would lower the water table generally to below the transported cover, but the old anomalous redox zone (Fe oxides) is likely to retain a geochemical signature of mineralisation (Fig. 1B; Anand *et al*. 2016).

Displaced anomalies can also form in transported cover sequences. For example, Zn and Cu concentrated in Fe and Mn oxides at redox fronts, may be derived by leaching from the transported cover, and be unrelated to any proximal basement mineralisation (Anand 2016). Such anomalies may be distinguished as false by regression analysis or by the absence of a multi-element signature – but with no certainty if the primary mineralisation itself lacks other elements, or only Cu and Zn have been mobilised. Conversely, the transported cover itself may have a high, multi-element background, or contain low grade mineralisation.

Geology

The Yilgarn Craton comprises an area of approximately 657,000 km^2 and forms one of the largest intact segments of the Archaean crust on Earth. Much of the Yilgarn Craton is a granite-greenstone terrain characterised by arcuate 'greenstone belts' of metamorphosed sedimentary and volcanic rocks that lie between large areas of granitoid rocks. The bulk of the Craton is thought to have formed between 3000 and 2600 Ma, with some gneissic terrains older than 3000 Ma in age (Myers 1993). The greenstones hosting orogenic gold mineralisation are ultramafic and mafic volcanic rocks formed as extensive submarine lavas, with local centres of felsic and mafic volcanic rocks.

The Albany Fraser Orogen is an arcuate Mesoproterozoic orogenic belt adjacent to the southern and southeastern margins of the Archaean Yilgarn Craton in Western Australia. It comprises two main tectonic units that reflects its relationship with the Yilgarn Craton: the Northern Foreland and the Kepa Kurl Booya Province. Northern Foreland consists of greenschist and amphibolite to granulite facies Archaean gneisses and granites. The Kepa Kurl Booya Province is defined as the crystalline basement of the Albany Fraser Orogen (Spaggiari *et al*. 2009).

The Paterson Orogen in Western Australia covers around 30 000 km^2 to the east of the Hamersley Basin and southwest

continued on page 6

Gold dispersion in transported cover sequences especially in… *continued from page 5*

of the Canning Basin. It consists of Early to Middle Proterozoic high grade metamorphic rocks, acid and basic intrusive rocks, shelf sediments and minor younger granite intrusive rocks. The region contains poorly exposed Neoproterozoic sedimentary successions in the northwest Paterson Orogen which are host to significant deposits of gold-copper, base metal and uranium (Bagas 2004).

Geochronology of weathering

In the Yilgarn Craton and the Albany Fraser and Paterson orogens of Western Australia, a deeply weathered mantle, many metres thick, is commonly overlain by transported cover of various ages. Although there is palaeomagnetic evidence for regolith ages as old as the Carboniferous on the Yilgarn Craton (Pillans 2005), glaciation in the Permian eroded most pre-existing regolith, leaving poorly consolidated transported cover that, in places, has since been weathered. Most of the preserved deeply weathered regolith has formed during the Late Cretaceous to Miocene (Anand & Paine 2002). Recently, there has been dating of ferruginisation of the deeply weathered mantle. Palaeomagnetic dating of hematite in weathering profiles from several locations in the Yilgarn Craton indicates two major periods of hematite formation (Pillans 2005; Anand & Robertson 2012). These include Maastrichtian to Palaeocene (60-75 Ma) and Late Miocene (10 Ma). (U-Th)/He dating of ferruginous nodules and pisoliths formed from the weathering of bedrock at the Garden Well gold deposit indicate an age of 15 Ma whereas ferruginous pisoliths formed in the Eocene-Miocene transported cover yield ages of 11-19 Ma (Anand, Wells & Salama, unpublished data). However, ferruginous pisoliths in the Darling Range of Western Australia are slightly younger as suggested by 10 -7.5 Ma (Pidgeon *et al*. 2004) and 5.7-1.3 Ma ages obtained by (U-Th)/He dating (Wells *et al*. 2018). Conditions were warm and humid from the Late Cretaceous to the end of the Early Miocene, with fluctuations to at least two cooler and drier episodes prior to the Oligocene (McGowran & Li 1998), when the vegetation was dominated by coniferous forests and woodlands. During the Late Miocene, a seasonally drier and warmer climate (though rainfall was still greater than at present; Martin 2006), occurred with consequent flora changes, as southern Australia drifted northwards. Thereafter, generally drier conditions prevailed. Thus, weathering profiles resulted from the overprinting by several climatic changes, including water table fluctuations, together with variations in salinity and groundwater residence times.

Transported cover classification

It is important to understand the nature of the transported cover and its influence on metal dispersion processes. There are broadly three principal transported sequences (Fig. 2; Anand & Paine 2002; Butt *et al*. 2005): Sequence

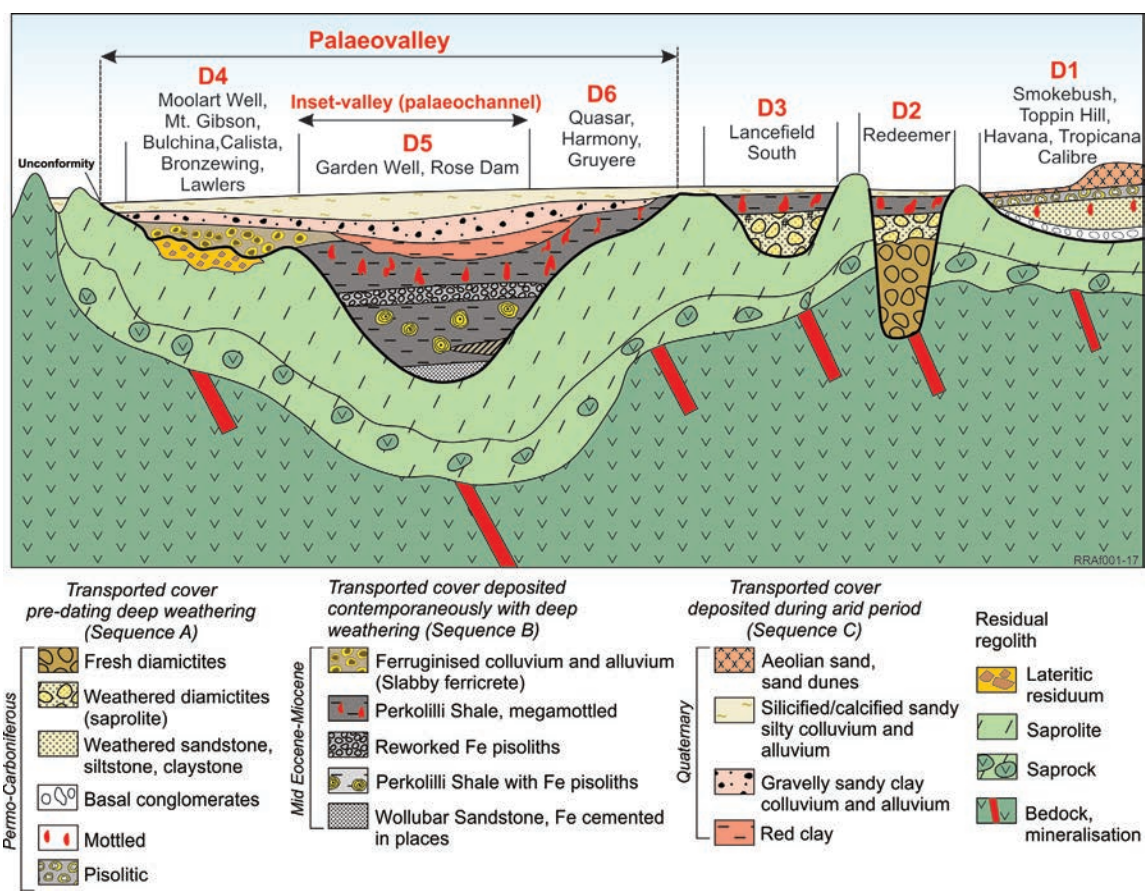

Figure 2. Classification and stratigraphy of some major transported cover units. D1-D6 represent different transported cover environments discussed in the text.

continued on page 8

Gold dispersion in transported cover sequences especially in… *continued from page 6*

A (*transported cover pre-dating deep weathering; Permo-Carboniferous), Sequence B (transported cover deposited contemporaneously with weathering; Mid Eocene-Miocene)* and *Sequence C (transported cover deposited during an arid period; Quaternary)*. These sequences can be further sub-divided according to the nature of the transported material (Fig. 2). In Western Australia, there has been post-depositional weathering and diagenesis of transported cover (Fig. 3). Older transported cover (Sequences A and B) is strongly ferruginised (goethite, hematite) as a result of wet-dry climatic changes during the Palaeocene and more commonly Miocene whereas transported cover of Sequence C, deposited in the arid period has been subjected to silicification, calcification and gypsification to form red-brown hardpan (silicified colluvium and alluvium), calcrete and gypcrete respectively (Anand 2005; Fig. 3). These principal transported cover sequences, briefly described below, are used as a framework for several case studies reported here from the Yilgarn Craton and the Albany Fraser and Paterson orogens of Western Australia (Fig. 4).

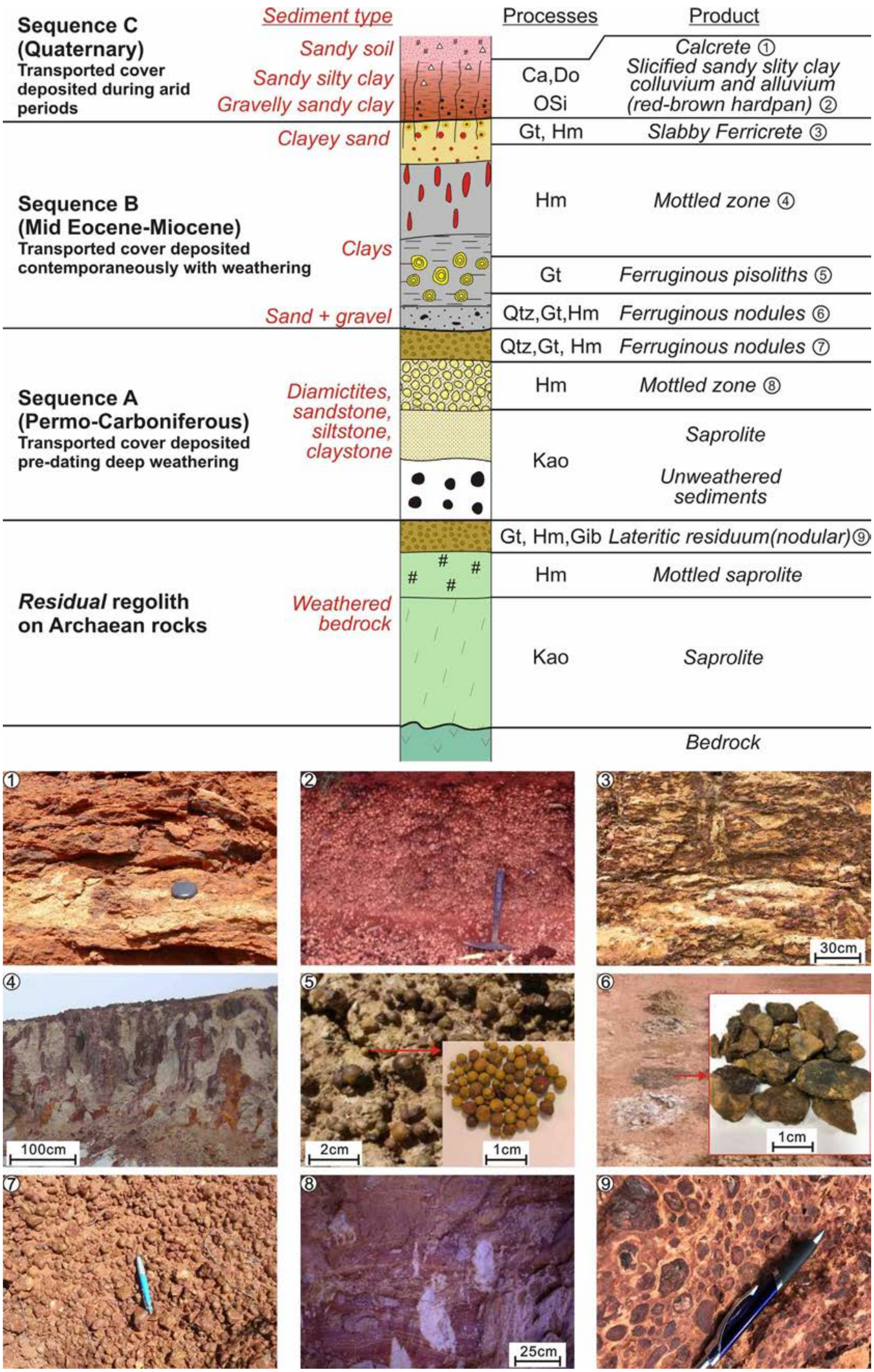

Figure 3. Post-depositional weathering and diagenetic features of transported cover units (modified after Anand 2005). 1 to 9 are photographs of some products that result from post-depositional weathering. See legend in Figure 2 for the different units. Ca-calcite; Do=dolomite; OSi=Opaline silica; Gt=goethite; Hm=hematite; Qtz=quartz; Kao=kaolinite; Gib=gibbsite.

continued on page 9

Gold dispersion in transported cover sequences especially in… *continued from page 8*

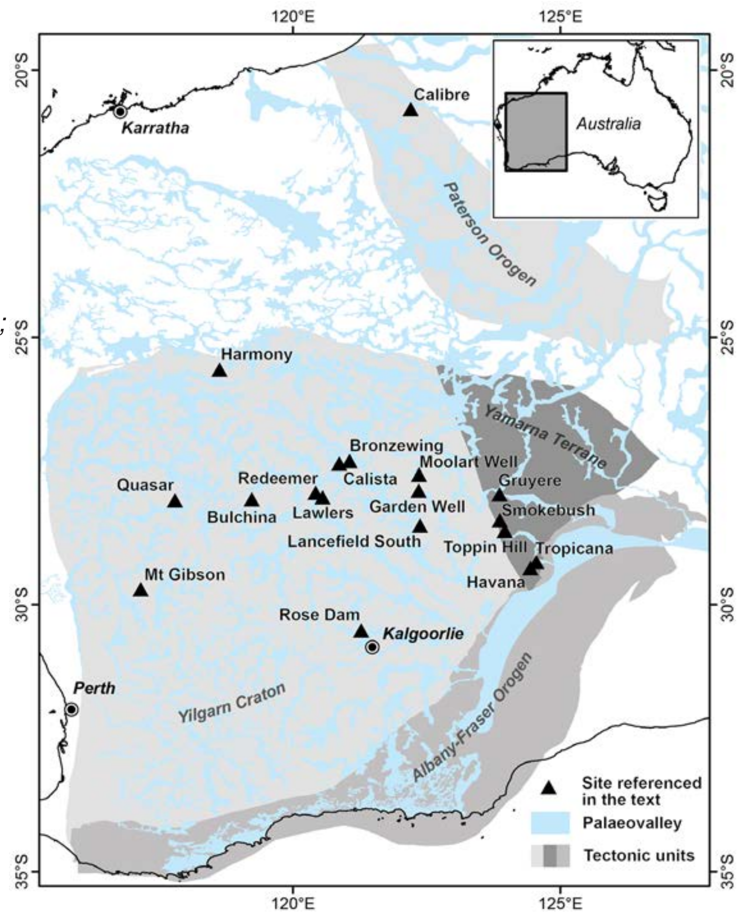

Figure 4. Location of the sites referred to in the text on Multi-resolution Valley Bottom Flatness (MrVBF) map (after Gallant & Dowling, 2003). MrVBF is a topographic index which identifies domains of deposited transported material at a range of scales and is based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones (DEM Source: Geoscience Australia 2009). Location of the study area in Australia is also shown in the inset.

Sequence A (*transported cover pre-dating deep weathering; Permo-Carboniferous)*

Overlying Archaean crystalline basement in the eastern and north-eastern Yilgarn Craton and the Albany Fraser and Paterson orogens of Western Australia are scattered remnants of Gondwanan Permo-Carboniferous fluvio-glacial transported cover that forms successions up to 150 m thick. The Permo-Carboniferous transported cover was produced by glacial erosion of the palaeohighs in the surrounding Archaean and Proterozoic basement, under a cold, arid climate (Salama & Anand 2017). The transported cover comprises boulder-rich diamictite, sandstone, siltstone and claystone filling broad or shallow valleys (Fig. 2). Transported cover in the shallow valleys in an undulating landscape is commonly proximally derived whereas, in broad valleys, it is more distally derived. Topographic variations cause significant lateral variations in thickness of the Permian succession, which pinches out toward the basement palaeohighs (Salama *et al*. 2016a; Salama & Anand 2017). Permo-Carboniferous transported cover and underlying bedrock were subjected to intensive, post-Permian chemical weathering (Eyles & de Broekert 2001; Anand & Paine 2002; Anand & Robertson 2012; Salama & Anand 2017; Salama & Anand, 2018a,b). Permian transported cover is commonly poorly indurated, strongly weathered and ferruginised (resulting in mottling, and the development of nodules and pisoliths). Some of the deeper glacial deposits and underlying bedrock are unweathered. Thus, several exploration environments can be encountered in areas dominated by Permian transported cover (Fig. 2), including fresh to highly weathered clays with or without strong ferruginisation (chemical interface) towards the top of the succession. Permian transported cover may be overlain by Sequences B and C, described below.

Sequence B (transported cover deposited contemporaneously with weathering; Mid Eocene- Miocene)

Large broad palaeovalleys representing older drainage systems are mantled with deeply weathered profiles. Both the palaeovalleys and the overlying weathered material were incised by smaller inset-valleys ('palaeochannels'; Fig. 2). Major incision occurred in the Middle Eocene and was primarily caused by epeirogenic uplift of the Yilgarn Craton (de Broekert & Sandiford 2005). Filled inset-valleys form a large buried network in the Yilgarn Craton and may occupy up to 30% of the landscape. They are many kilometres long and up to 1-2 km wide (Anand & Paine 2002).

continued on page 10

Gold dispersion in transported cover sequences especially in… *continued from page 9*

The nature of the transported cover varies between the palaeovalleys and inset-valleys (Fig.2). In palaeovalleys, the transported cover is shallow and largely consists of colluvial-alluvial detritus, derived locally from upslope erosion that accumulated on footslopes and valley floors within a toposequence. Iron oxide cementation of detritus in palaeovalleys formed ferricrete (chemical interface; Anand *et al*. 2019). Ferricretes are generally underlain by lateritic residuum, which is formed from weathering of underlying bedrock. Overprinting of ferricretes has occurred in palaeovalleys as the transported cover was subsequently reweathered by groundwater in the presence of organic matter. Goethite and kaolinite were precipitated to form yellow cortices and authigenic pisoliths, and voids and cracks were filled. Evidence for the interaction of vegetation and microbes with ferricrete is preserved in root channels, organic carbon and microbial fossils, confirming significant biological modification (Anand *et al*. 2017, 2019).

Transported cover in inset-valleys is alluvial, lacustrine or estuarine (Kern & Commander 1993; Anand & Paine, 2002; de Broekert & Sandiford 2005). At the base of an inset-valley, transported cover is a coarse-grained (sand and gravel) fluviatile unit of Middle to Late Eocene (the Wollubar Sandstone; physical interface). This unit is unconformably overlain by a clay-rich unit of probable Oligocene-Miocene age (Perkolilli Shale; Kern & Commander 1993). Transported cover is up to 100 m thick and was derived from erosion of a pre-existing weathered profile. The inset-valley transported cover is commonly overprinted by ferruginisation and in places by silicification, calcification and dolomitisation. Ferruginisation (chemical interface) is widespread as megamottles or nodules, pisoliths or massively cemented zones at upper levels, mostly, but not exclusively, above the modern water table (Anand & Paine 2002).

Sequence C (transported cover deposited during the arid period; Quaternary)

A wide range of transported cover (colluvial, alluvial, aeolian, evaporitic) may overlie not only fresh and weathered basement, but also the older cover, and consist of their physical and chemical weathering products. This type of transported cover, a few metres to 25 m thick, is derived from the combination of increased erosion of the land surface due to tectonic uplift, and a shift to more arid conditions during the Late Miocene to Quaternary (Anand & Paine 2002). At many sites, the colluvium-alluvium is composed of two major sedimentary units: an upper yellow to red, sandy silty clay and a lower, red-brown, gravelly sandy clay. Viewed together, the sandy silty clay and gravelly, sandy clay units represent an inverted stratigraphy in relation to the residual regolith from which they were derived, in that material derived from the upper ferruginous duricrust occurs at the base of this surficial transported cover. The sandy, silty clay unit varies from 2 to 10 m thick, and overlies ferruginous duricrust, saprolite or more commonly a gravelly sandy clay unit; that is derived by erosion of saprolite and saprock. The upper parts of the transported cover have been variably silicified and calcified (chemical interface) possibly enhanced by short periods of water saturation (Anand & Paine 2002).

Quantification of weathering of transported cover

Weathering indices can provide a quantitative measure of the extent of weathering of bedrock and transported cover. Several weathering indices (e.g., Ruxton Ratio, Weathering Index of Parker, Vogt's Residual Index, Chemical Index of Alteration, Chemical Index of Weathering, Plagioclase Index of Alteration, Silica-Titania Index), have been proposed to characterise the intensity of weathering and weatherability depending upon the nature and requirement of the study (Price & Velbel, 2003). Among the weathering indices evaluated by Price & Velbel (2003), the weathering index of Parker (1970, referred to here as WIP) is the most appropriate, because it includes the highly mobile alkali and alkaline earth elements (Na, K, Mg, Ca) in its formulation

$$((100)[(2Na_20/0.35)+(MgO/0.9)+(2K_2O/0.25)+(CaO/0.7)])$$

thus yielding values that differ greatly from those of the parent rock. In addition, the WIP allows for Al mobility, unlike other weathering indices. The WIP is >100 for fresh rock whereas for highly weathered rock it is 0. Figure 5 shows the WIP for various transported cover units in three sequences from various localities in the Yilgarn Craton. Residual regolith (saprock, lower, middle and upper saprolite) is also included for comparison. As expected, the WIP of saprock (median 73) and lower saprolite (median 53) are much greater than middle (median 27) and upper saprolite (median 10). The WIP values for three sequences are less than 20 with the exception of fresh diamictite (median 97) suggesting the transported cover is highly weathered and weathering may have happened before or after deposition. Higher WIP indices in recent transported cover, compared to older transported cover reflect some minor smectite and illite formation during the arid period (Anand & Paine 2002).

continued on page 11

Gold dispersion in transported cover sequences especially in…

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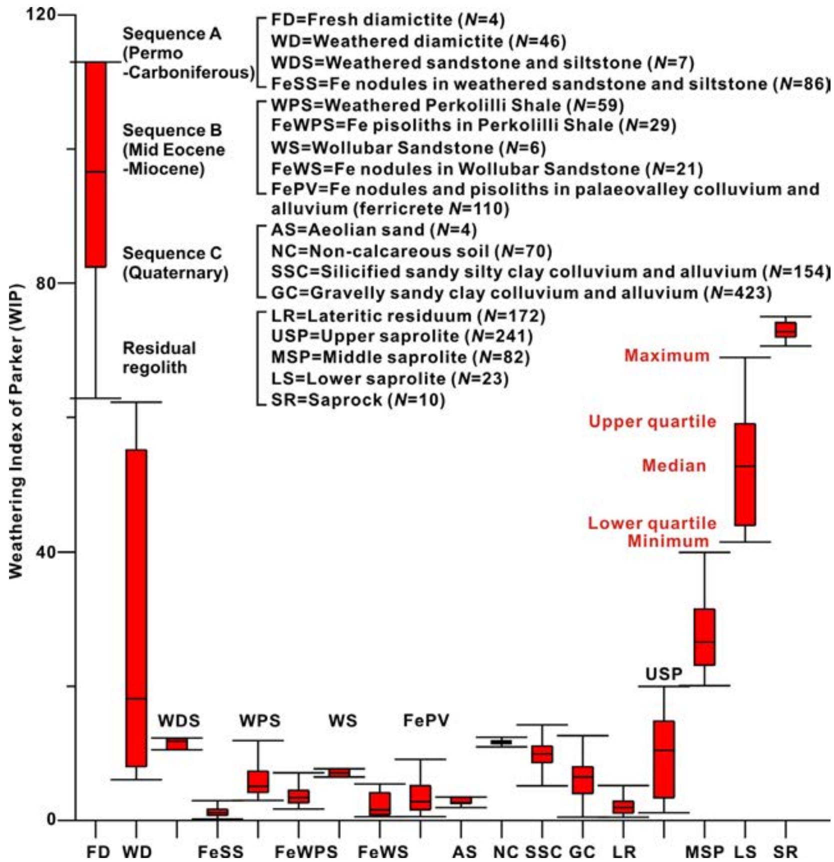
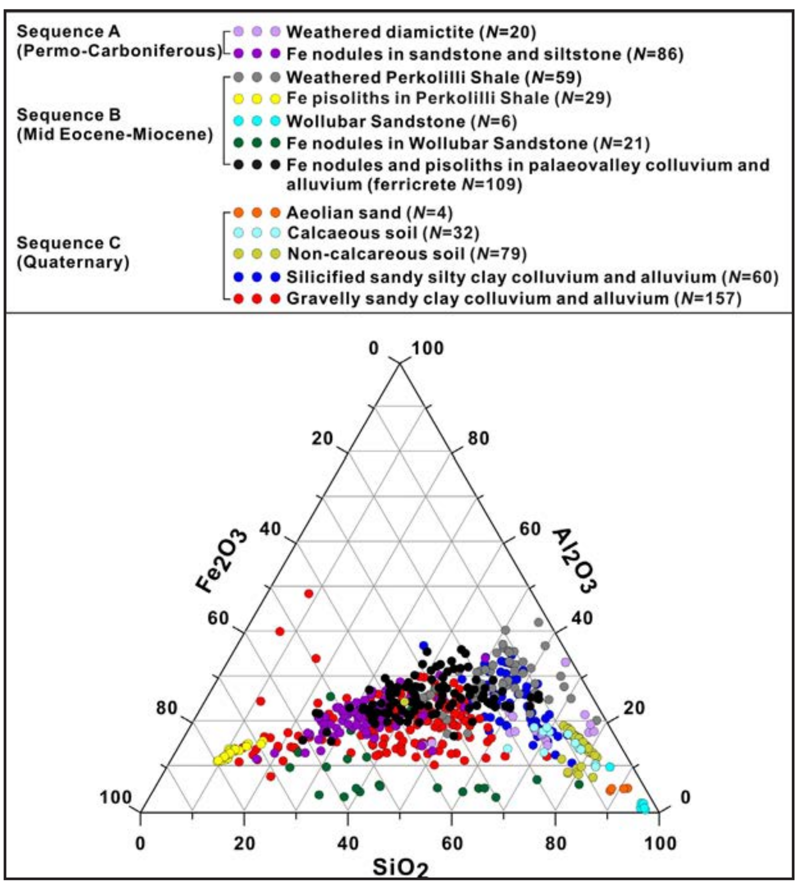


Figure 5. Comparison of Weathering Index of Parker (WIP; Parker 1970) values for transported cover collected from various regolith studies. The Parker index was calculated using the formula: (100)[(2Na$_2$0/0.35)+(MgO/0.9)+(2K$_2$O/0.25)+(CaO/0.7)]. Upper saprolite also includes samples from the plasmic zone.

Si, Al and Fe in transported cover

Silica, Al and Fe distributions show the extent of silicification, kaolinisation and ferruginisation of transported cover (Fig. 6). Although ferruginisation can occur in any type of transported cover, older cover is generally strongly ferruginised to form nodules and pisoliths compared to recent cover that is silicified to form red-brown hardpan. Ferruginous pisoliths in the Perkolilli Shale differ from ferruginous nodules in weathered diamictites and the Wullabar Sandstone by having abundant Fe as goethite and much less Si and Al (as quartz and kaolinite). In addition to hematite and goethite, quartz is important in ferruginous nodules formed in the Wullabar Sandstone and diamictites. There is an overlap of the Perkolilli Shale with weathered diamictites but weathered diamictites are more quartz-rich. Recent gravelly colluvium and alluvium can be distinguished from silicified colluvium and alluvium by having abundant Fe (as hematite, goethite, maghemite) as detrital clasts and less Si (opaline Si and quartz). The Wollubar Sandstone and aeolian sand are Si-rich.



Identification of transported cover

Transported cover can be distinguished by an obvious textural and chemical discordance with the underlying residual regolith, preserved sedimentary structures and poorly ordered kaolinite (Anand & Paine 2002). The selection of elements used to identify transported cover from residual regolith should be based on their immobility in the weathering environment, so as to remain in high concentrations in a weathering profile (Hallberg 1984). Zirconium and Ti are very widely used as immobile elements, mainly because they occur in most rocks only as the minerals zircon, anatase and rutile, which are resistant to weathering. Two environments where the inset-valley and Permian

Figure. 6. Ternary diagram showing composition of various categories of transported cover in terms of Al, Si and Fe content.

continued on page 12

Gold dispersion in transported cover sequences especially in… *continued from page 11*

transported cover overlie saprolite (Fig. 7) may be compared in this way. In both cases, Ti/Zr ratios are useful for discriminating transported cover from underlying *in situ* regolith (Fig. 7). However, Ti/Zr ratios do not clearly separate the weathered diamictite from inset-valley clays and recent colluvium and alluvium. This implies that all types of transported cover in this environment are derived from a similar lithology (felsic) and are unrelated to the underlying mafic-ultramafic basement.

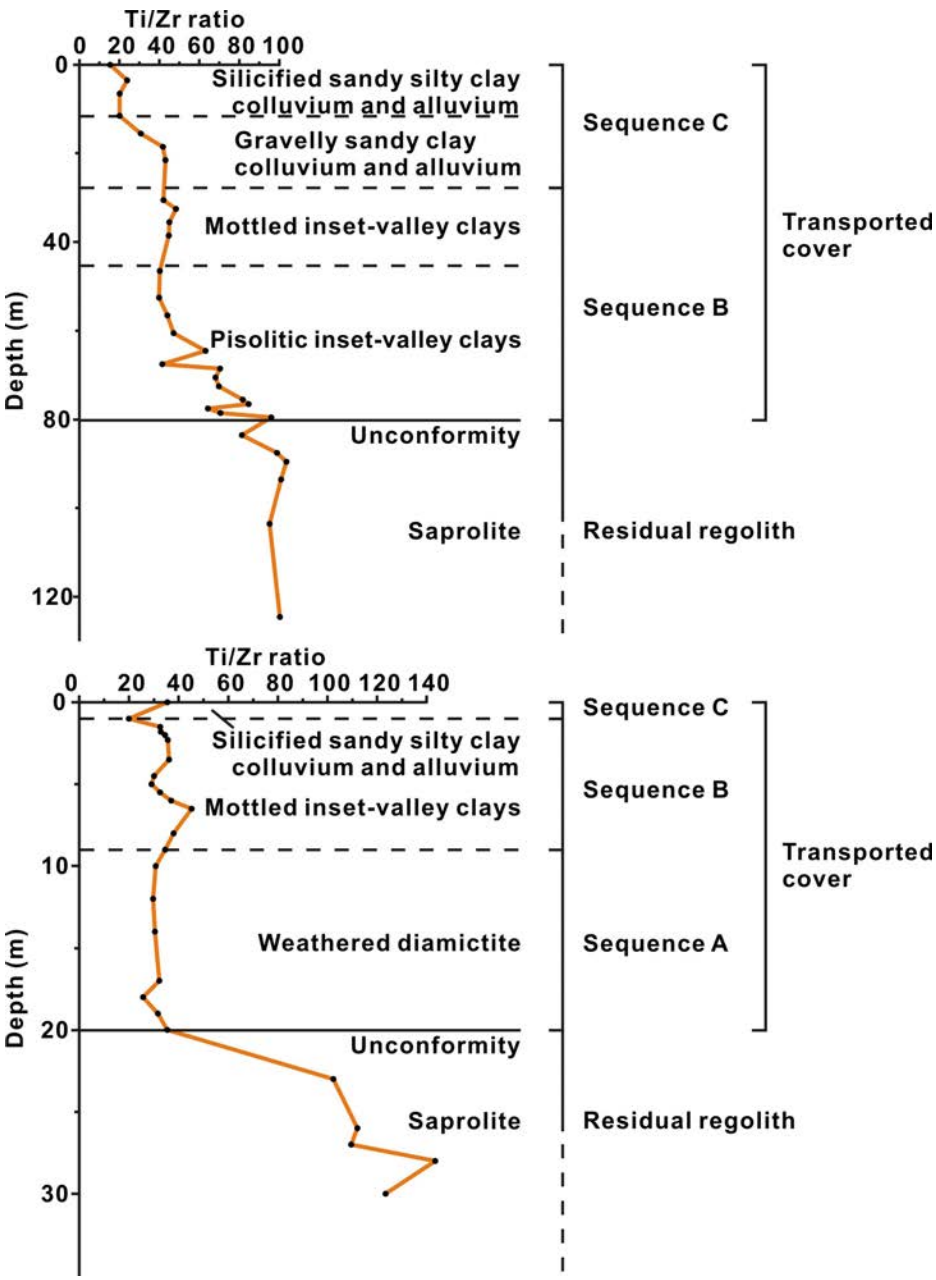


Figure 7. Ti/Zr ratios showing discrimination of transported cover from residual regolith. Two types of transported cover environments are compared.

Metal dispersion in Sequence A (transported cover pre-dating deep weathering; Permo-Carboniferous)

Examples of dispersion from gold deposits into Permian transported cover are from Toppin Hill and Smokebush (Salama & Anand, 2018a,b), Havana and Tropicana (Lintern *et al*. 2009), Calibre (Noble *et al*. 2019), Redeemer (Baker 1991; Carver *et al.* 2005), and Lancefield South (Anand & Robertson 2012). Toppin Hill and Smokebush (Yamarna Terrane), Havana and Tropicana (Albany Fraser Orogen) and Calibre (Paterson Orogen) represent the D1 environment (Figs. 2 and 4) where extensive sheets of quartz, goethite-hematite-rich authigenic ferruginous nodules and pisoliths (palaeoredox front) occur at the top of Permian transported cover that are typically overlain by recent aeolian sand, the lower part of which may also contain authigenic pisoliths and nodules. Here, the Permian transported cover is deeply weathered and consists mainly of coarse-grained gravelly, kaolinitic and micaceous (illite and muscovite-rich) saprolitic sandstones and siltstones at the base, grading upwards into mottled, cross-laminated sandstones and siltstones with a variety of dissolution features such as dissolution-collapse brecciation. This type of transported cover is markedly different from Permian glacial diamictites (e.g., Redeemer, Lancefield South) in the northeast part of the Yilgarn Craton (Anand & Robertson 2012; Salama *et al*. 2016a; Salama & Anand 2017). At the Redeemer and Lancefield South gold deposits, authigenic nodules and pisoliths are not developed but the transported cover is mottled near the top. Redeemer provides an example of mechanical dispersion of mineralised detritus into Permian transported cover (environment D2; Fig. 2) whereas the Lancefield gold deposit provides an example of initial mechanical to residual dispersion followed by hydromorphic dispersion at the palaeoredox front (environment D3; Fig. 2).

Toppin Hill, Smokebush, Havana, Tropicana and Calibre gold deposits (environment D1)

The Yamarna greenstone belt (Smokebush, Toppin Hill) is dominated by metamorphosed mafic rocks, with less common ultramafic, felsic metavolcanic and volcanoclastic rocks, clastic metasedimentary rocks and chert units (Bath *et al*. 2016). The Toppin Hill mineralised lode, which is only 5-10 m wide, contains Au (3-21 ppm), Cu (210-500 ppm), S (7150 ppm-1.26 %), Zn (<100 ppm) and Pb (<20 ppm). The Permian transported cover at this prospect is up to 45 m thick

continued on page 13

Gold dispersion in transported cover sequences especially in… *continued from page 12*

(Salama & Anand 2018a,b). Here, authigenic pisoliths developed in Permian transported cover are overlain by up to 6 m of aeolian sand. The residual weathering profile is mainly bleached kaolinitic saprolite over granitoids, and ferruginous saprolite over felsic volcanics and metabasalt. Gold in the Permian transported cover sequence varies between 10 and 100 ppb and is in high concentrations in the upper mottled sandstones and the basal gravelly sandstones and conglomerates, compared to concentrations in siltstone intercalations. Forty eight samples of authigenic nodules and pisoliths were collected for analysis from near the surface (10-30 cm). Results for Au from two traverses from Toppin Hill (Fig. 8) show that Au in authigenic pisoliths clearly reflects the buried mineralisation. In traverse 1, Au reaches 30 ppb over the mineralisation compared to a background of less than 10 ppb (Fig. 8A). Similarly, strong Au anomalies (Au 52-605 ppb) were identified in traverse 2 over the mineralisation (Fig. 8B). This indicates that gold has been dispersed chemically from the mineralisation through the Permian cover to the authigenic pisoliths above. During Palaeocene-Miocene wet climatic events, the water table could have been near the surface with metals dispersing from buried weathered ore to the top of the water table. This may have led to mobilisation and precipitation of metals from the residual weathering profile through the Permian transported cover. The area in general is strongly faulted and fractured but the extent of faulting in Permian cover is unknown. Therefore, the role of geochemical dispersion through fractures at Toppin Hill is unclear.

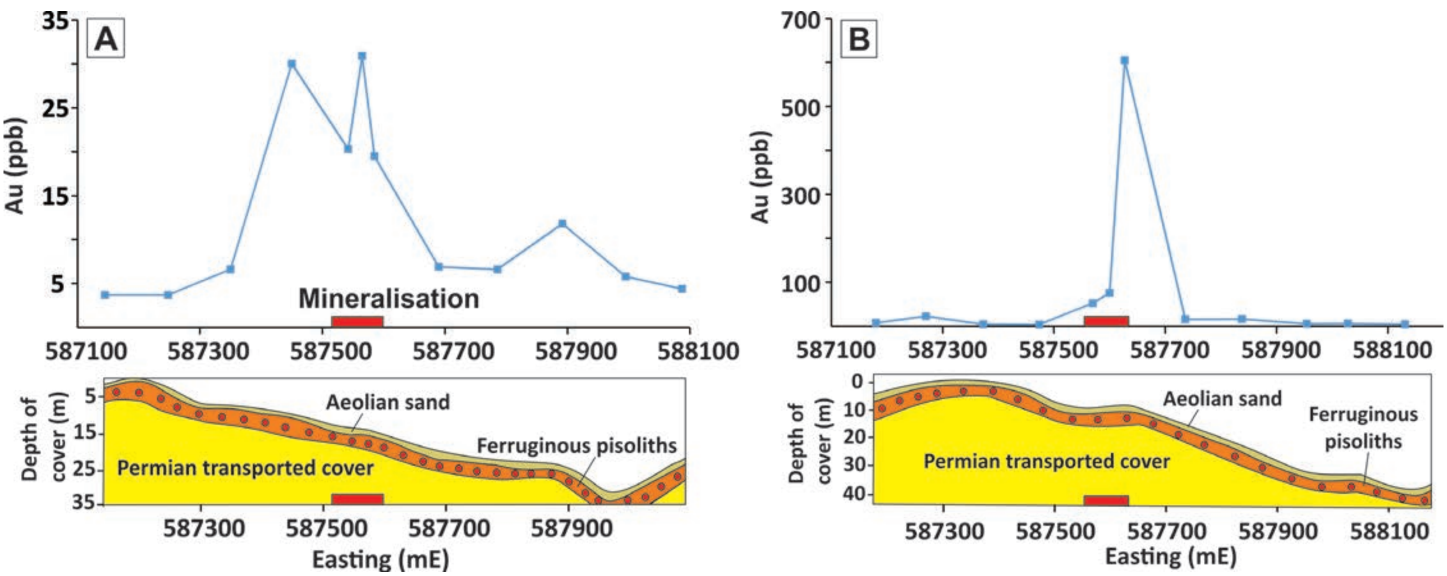


Figure 8. (A,B) Regolith cross sections showing variation in transported cover for two traverses, Toppin Hill gold prospect. Elevated gold contents in authigenic ferruginous pisoliths (red dots in orange unit) developed at the top of Permian cover indicates the location of mineralisation.

At Smokebush, mineralisation occurs within a 25 m wide shear zone in quartz-rich metadolerite, over a 800 m long strike length with localised quartz and sulphide lode structures (Bath *et al*. 2016). The ore zone contains Au (11 ppm), As (7.10 %) and S (3.58 %). The Permian transported cover is 5-30 m thick and rest unconformably on a 25-60 m thick saprolite developed over sheared dolerite (Salama & Anand 2018a,b). The unconformity between the Permian transported cover and the underlying saprolite is marked by a basal gravelly layer of rounded, quartz-rich clasts. There are two types of ferruginous materials at the 2-10 m thick palaeoredox front at the top of the Permian transported cover. These are, (i) quartz-hematite-goethite-rich authigenic nodules and pisoliths (<20 mm diameter) in recent quartz-rich aeolian sand and (ii) hematite-gibbsite-rich reworked ferruginous gravel formed from weathering of underlying rock. One hundred and twelve samples of ferruginous nodules and pisoliths were collected from shallow (<10 m) drilling and the near surface (Salama & Anand 2018b). The authigenic ferruginous nodules and pisoliths have anomalous Au and As concentrations over bedrock mineralisation (Salama & Anand 2018a). Gold varies from 1 to 135 ppb with the majority of samples >11 ppb over mineralisation against a background of <4 ppb. Gold concentrations in authigenic pisoliths and nodules are greater than most of the underlying reworked ferruginous gravel, except in three drill holes, where Au reaches 384 ppb in reworked gravel. Conversely, the As content is greater in the reworked gravel than in the authigenic nodules and pisoliths, except for one drill hole where As reaches 2880 ppm in the authigenic pisoliths. The Permian transported cover underneath these materials is barren with respect to Au, except at the interface between the saprolite or bedrock and the Permian cover. It is concluded that the formation of anomalies in the authigenic ferruginous nodules and pisoliths indicates active hydromorphic dispersion and bioturbation through cover, whereas displaced ferruginous gravel anomalies highlight the role of the mechanical processes along slope. Thus, understanding palaeolandscape evolution and the metal dispersion mechanisms is critical for interpreting the formation of surface and interface anomalies.

continued on page 14

Gold dispersion in transported cover sequences especially in… *continued from page 13*

The Tropicana-Havana gold deposit is hosted within Neoarchaean gneisses of the Plumridge Terrane that occurs along the eastern margin of the Archaean Yilgarn Craton in the Albany Fraser Orogen. Mineralisation is located in a metasyenite of the Tropicana Gneiss (Doyle *et al*. 2017). Sulphides within the ore zones are dominated by fine pyrite (2-8%, <0.2mm) and minor chalcopyrite, electrum and tellurides. Although lacking significant supergene enrichment, the dominance of mineralised basement-derived clasts in the upper part of the transported cover were ore-grade and contributed mineable material at Havana (Doyle *et al*. 2017). Open pit operations at Tropicana are distributed along a northeast trending mineralised corridor 1-2 km wide and 5 km long. Along this trend, the ore deposit is partitioned by east to east-southeast shears into four principal zones from north to south; Boston Shaker, Tropicana, Havana and Havana South (Doyle *et al*. 2017).

At Tropicana-Havana, both basement and transported cover have undergone weathering to 40-50 m since emplacement (Lintern *et al*. 2009). Saprolite is unconformably overlain by 10-20 m thick Permian transported cover that are in turn overlain by recent 2-10 m thick aeolian sand (Fig. 9A) similar to the Smokebush and Toppin Hill gold deposits. On higher ground, particularly at Havana, ferricrete is 2-3 m thick and consists largely of authigenic goethite- and quartz-rich ferruginous nodules and pisoliths and a few detrital hematite-rich pisoliths (Fig. 9B). Where ferricrete has been eroded, it forms a dispersion train down slope. The accumulation of Fe to form cemented nodules and pisoliths (ferricrete) on the rise upslope to the Havana deposit is thought to reflect topographic inversion (Lintern *et al*. 2009). Ferruginous nodules and pisoliths were collected where available from drill cuttings, small pits and from the surface. At Havana, surficial nodules and pisoliths were absent above mineralisation and therefore could not be analysed but samples upslope of the projected mineralisation were strongly anomalous (550 ppb Au) (Fig. 9C; Lintern *et al*. 2009). Laser ablation ICP-MS analysis of ferruginous nodules and pisoliths shows that Au and Cu are controlled by goethite that mainly occurs in the cortex of pisoliths (Fig. 9D). At Tropicana (not shown), anomalous concentrations of Au (up to 18 ppb) occur over the mineralisation.

The Calibre Au-Cu-Ag-W deposit is located in the Paterson Orogen of Western Australia. The geology of the Calibre deposit is Proterozoic, with predominantly sulphide bearing metasediment hosted hydrothermal shear, fault and strata/

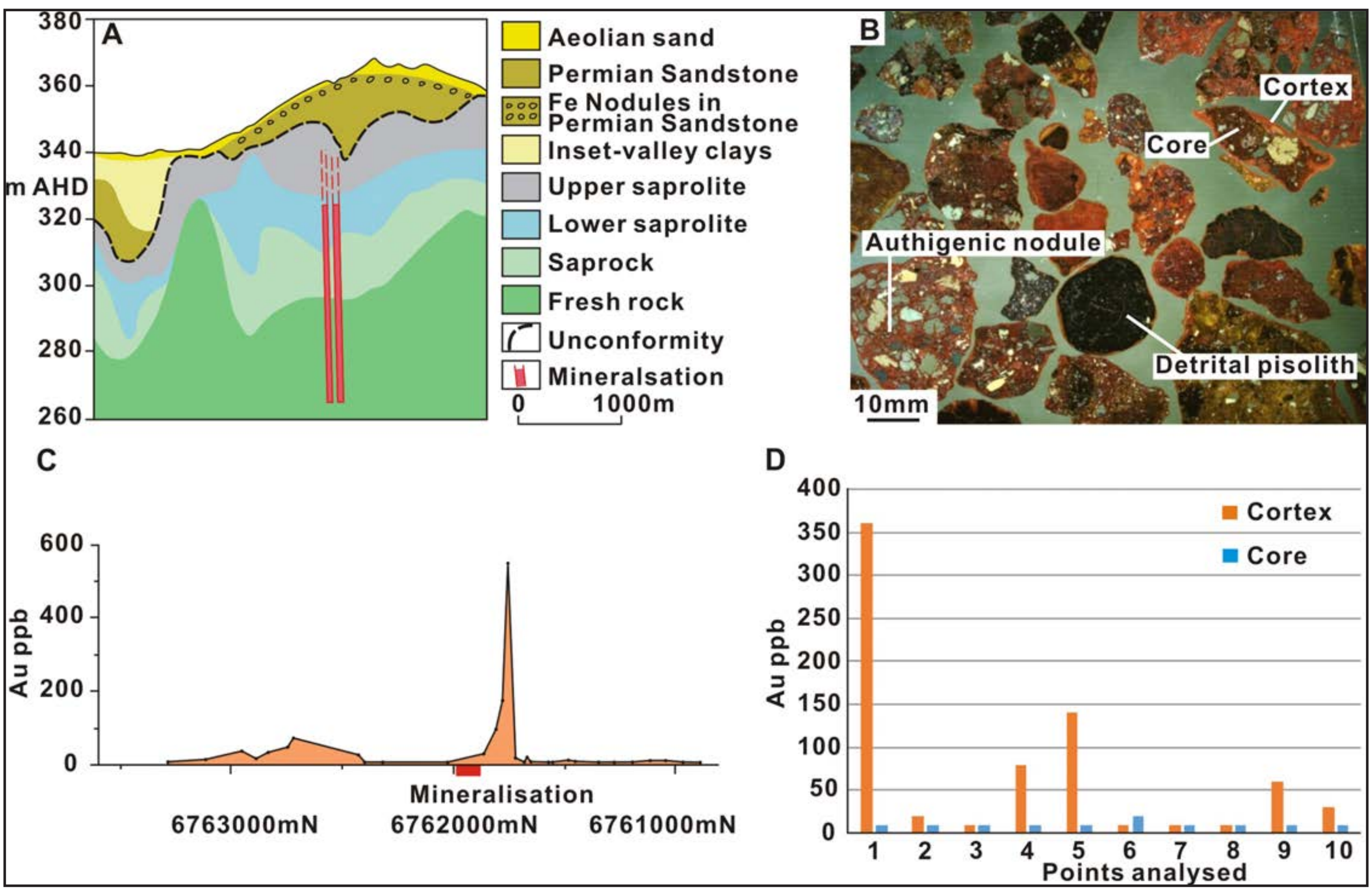


Figure 9. (A) Regolith cross section for the Havana gold deposit (modified after Anon, 2009). (B) photograph of ferruginous nodules and pisoliths showing the internal structure of authigenic and detrital pisoliths. (C) Gold content in the whole samples of ferruginous nodules and pisoliths developed at the top of Permian cover locates the mineralisation (modified after Lintern et al. 2009). (D) Laser ablation ICP-MS analysis of cores and cortices showing Au is more enriched in the cortices than the cores.

continued on page 15

Gold dispersion in transported cover sequences especially in… *continued from page 14*

contact controlled precious and/or base metal mineralisation. The mineralisation is thought to be granite related (Antipa Minerals, media release, January 2018). The deposit lies beneath 70 to 85 m of weakly consolidated and lithified Permian transported cover. The upper part of the Permian transported cover has been ferruginised to form a 5-10 m thick layer consisting of Fe nodules that are overlain by 5-15 m of recent aeolian sand. Samples from the interface between weathered and/or fresh rock and the overlying Permian transported cover and the interface between the ferruginous nodules at the top of Permian cover were analysed (Noble *et al.* 2019). At both locations, samples have anomalous concentrations of Au, Ag, Cu, As, Bi and W. Though there are much greater concentrations of W (up to 570 ppm) and Bi (up to 2.6 ppm) at the basement-transported cover interface, As and Ag are more abundant in the palaeoredox front (ferruginous nodules). Dispersion at the interface is largely mechanical, that at the palaeoredox front is chemical.

Redeemer and Lancefield South gold deposits (environments D2 and D3)
Redeemer

The Redeemer gold deposit lies within the western limb of the Lawlers antiform, in the northern part of the Norseman-Wiluna belt of the Yilgarn Craton (Fig. 4). From east to west, the stratigraphy of the western limb of the antiform consists of greenstone (layered gabbro, basalt and komatiites), overlain by metasedimentary rocks of the Scotty Creek Formation. The stratabound mineralisation is in a thick mafic metaconglomerate unit near the base of the Scotty Formation (Baker 1991). Permian transported cover is up to 25 m thick, consisting of rounded weathered granite boulders at the base, overlain by kaolinitic clays. A 5 m thick inset-valley overlying Permian transported cover contains a mixture of cobbles, ferruginous nodules, quartz and fresh mafic rocks clasts (Baker 1991).

Transported cover is underlain by residual regolith formed on basement. The depth of weathering of basement is about 50 m over the ultramafic rocks and about 25 m over the mafic metaconglomerates. Permian transported cover was investigated on a sampling grid of 10 x 2 m by combining drilling and pit wall samples (Baker 1991). There is a close correlation between Au and Bi distributions in the fresh rock and residual regolith over the mineralisation in the mafic metaconglomerate. Gold and Bi distributions show the same relationship in the Permian transported cover adjacent to the ore-bearing mafic metaconglomerate where the ore has been mechanically incorporated into the cover (Carver *et al*. 2005). In the near surface, the mafic metaconglomerate is depleted in Au relative to Bi. The relationship is similar for the Eocene-Miocene transported cover in the base of the inset-valley. Gold is dispersed from the weathered mafic conglomerates into the inset-valley cover. This dispersion is not associated with any obvious weathering in the transported cover and is likely to be mechanical (Carver *et al.* 2005).

Lancefield South

At Lancefield South, a 25 m thick deeply weathered ferruginised Permian fluvial sequence is exposed unconformably overlying weathered metamorphic Archaean rocks (Anand & Robertson 2012). The depth of weathering of the Archaean basement exceeds 50 m and is represented by well-developed kaolinitic and ferruginous saprolite. The bedrock consists of metakomatiites, metamorphosed Mg basalts, massive to pillowed mafic metavolcanics, carbonaceous shale and chert (Hronsky *et al.* 1990). The orebody consists of a mineralised zone some 140 m long and 7-12 m wide, enveloping a 5m wide lens of chert. The chert has a sulphide (pyrrhotite-pyrite-sphalerite-chalcopyrite-arsenopyrite) content of around 15% near the ore zone. Near the chert, the regolith developed on metamorphosed ultramafic rocks also contains significant supergene gold mineralisation (Hronsky *et al.* 1990).

The basal Permian is a coarse, matrix-supported conglomerate, consisting of a variety of rounded and angular metavolcanic, granitic and BIF cobbles and boulders, set in a gritty matrix of similar composition, interbedded with gritty, cross-bedded sandstones (Anand & Robertson 2012). The lower part is weathered to kaolinite, whereas the upper part is mottled. An inset-valley clay unit, 3-8 m thick, overlies the mottled Permian transported cover. Saprolite contains anomalous contents of Au and As. The Permian transported cover is enriched in Au (to 120 ppb), As (to 550 ppm) and Cu (to 150 ppm), with two distinct horizons enriched in Au. One is at the clay-rich base, and the other near the mottled top of the unit (Anand & Robertson 2012). The whole Permian transported cover sequence is anomalous in As, especially the middle to upper part. The Cu distribution is similar to that of As. Electron microprobe analysis of mineral phases showed that hematite and goethite are the main carriers of As (mean 1260 ppm) and Cu (mean 295 ppm) in mottled Permian cover. Basal inset-valley transported cover is also weakly anomalous.

Anomalies in ferruginised Permian cover were formed by residual to mechanical dispersion followed by post-depositional hydromorphic dispersion in later formed Fe oxides of mottles. Permian cover was deposited on residual soil, largely derived from mechanical breakdown of the basement containing some mineralised material, followed by limited weathering and pedogenesis. This formed anomalous concentrations of Au, Cu, Zn and As at the base of the Permian cover. However, strong dispersion (e.g., Au and As) not only occurred at the base but also at other levels, especially near the top of the Permian, largely associated with mottling which appears to represent a palaeoredox front or fronts associated with old water tables (Anand & Paine 2002).

continued on page 16

Gold dispersion in transported cover sequences especially in… *continued from page 15*

Metal dispersion in Sequence B (transported cover deposited contemporaneously with weathering; Mid-Eocene to Miocene)

Moolart Well gold deposit (environment D4)

There are two types of situations envisaged in this sequence as discussed above. These include (i) transported cover in a palaeovalley and (ii) transported cover in an inset-valley (Fig. 2). In the palaeovalley environment, the transported cover is strongly ferruginised to ferricrete (chemical interface) that is generally underlain by lateritic residuum. Ferricrete is nodular to pisolitic and occurs along the flanks of the inset-valley. Because of lateral dispersion in the palaeovalley, geochemical anomalies are large, measuring hundreds of metres to several kilometres in length for Au and pathfinder elements in pisoliths and nodules (e.g., Moolart Well, Mt Gibson, Bulchina, Empire and Gourdis gold deposits; Anand *et al*. 2019). However, ferruginous nodules and pisoliths may contain ore-grade gold with or without any known significant underlying primary mineralisation. Moolart Well (Fig. 4) typifies this environment where the ferricrete deposit extends over 4 km north-south and up to 1 km east-west (Fig. 10), and has an average thickness of 4 m (Balkau *et al*. 2017). The local

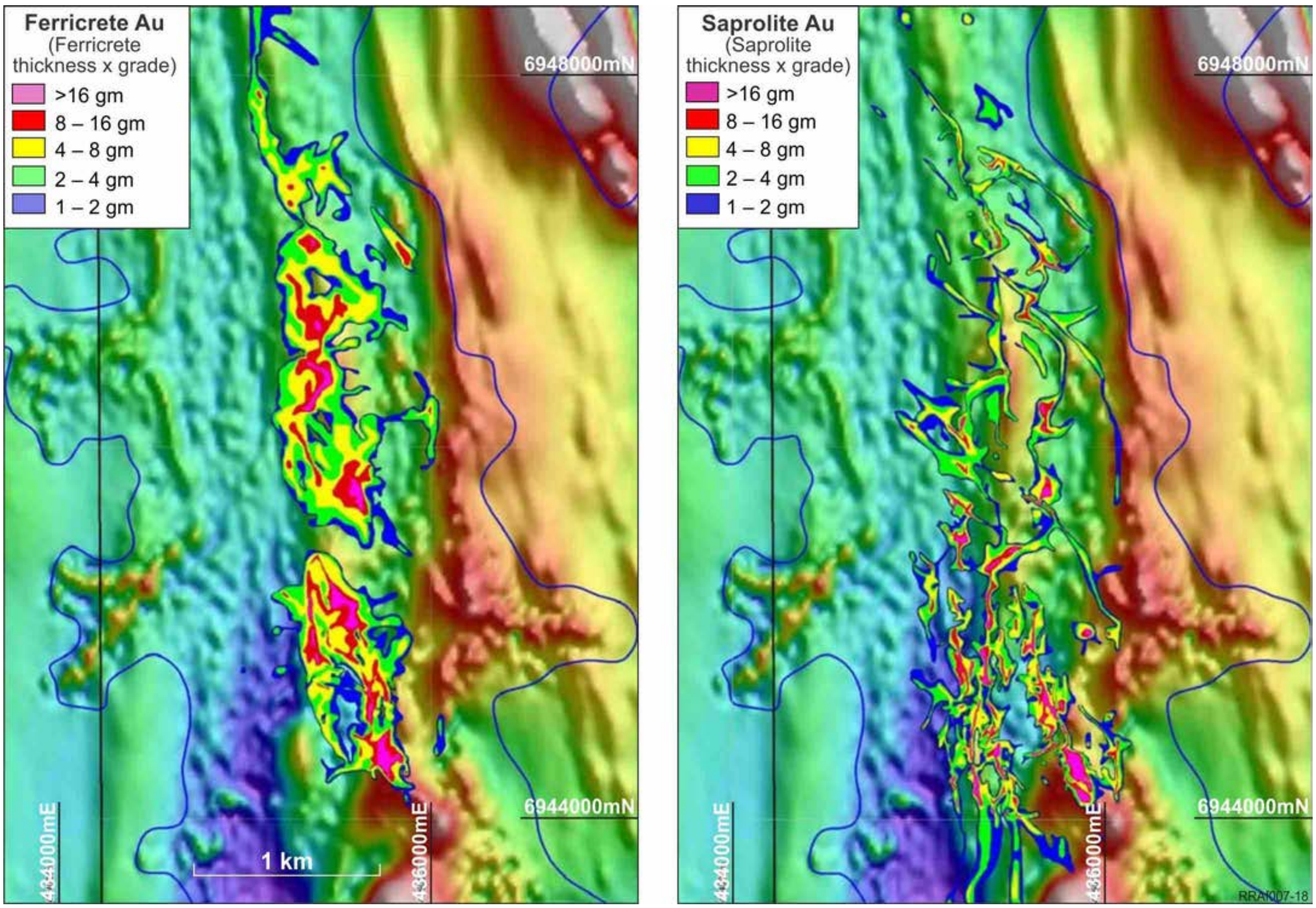


Figure 10. Gold concentrations in ferricrete and saprolite gold deposits, Moolart Well. Outline of inset-valley defined by magnetic imagery is also shown (blue line) (modified after Anand et al. 2017).

Archaean stratigraphy is a sequence of high Mg metabasalt with interbedded chert and sulphidic metasedimentary rocks (Balkau *et al*. 2017). The low-grade primary mineralisation (0.3–0.5 g/t Au; 103,000 ounces Au) beneath the ferricrete gold deposit is hosted predominantly in intermediate metadiorite intrusives within a north-trending shear zone. The principal economic deposits are secondary and confined to (1) an upper, flat-lying layer of goethite-coated ferruginous pisoliths formed in palaeovalley cover (1.19 g/t Au; 525,000 ounces Au); and (2) an underlying Au-bearing saprolite (0.75 g/t Au; 1,096,000 ounces Au), derived from weathering of the primary mineralisation (Balkau et al. 2017). The ferricrete gold deposit is overlain by younger silicified colluvium and alluvium (red-brown hardpan) which is 1–3 m thick on the east side and increases to >10 m along the western side of the ferricrete gold deposit.

Four hundred and seven samples of ferricrete, silicified colluvium and alluvium, soil and weathered bedrock, each approximately 1 kg, were collected and analysed from eight profiles at 0.25 m vertical intervals to depths of 12-15 m through the deposit (Anand *et al*. 2017). The highest concentrations of Au (to 10360 ppb) in ferricrete are similar to the concentration in the mineralised saprolite (to 9030 ppb) but high concentrations (to 6650 ppb) also occur over

continued on page 17

Gold dispersion in transported cover sequences especially in… *continued from page 16*

unmineralised saprolite, where the overall concentration relative to the saprolite is over x10 or more. In contrast, there are significant As concentrations (>500 ppm) in ferricrete over mineralised saprolite, but are greatly reduced (50–100 ppm) distant from mineralised saprolite. Furthermore, the data demonstrate a preferential enrichment of Au in pisoliths with goethite-coated cortices (Anand *et al*. 2017). Gold characteristically shows an increase in grade and purity (no Ag) in ferricrete compared to the underlying saprolite. Gold in nodules and pisoliths is mostly secondary (Ag-poor) nanometre- to micron-sized spheres, irregular, chains, hexagons, triangles and wires in precipitates of organic C, goethite, kaolinite and amorphous Si within cortices, cracks and cavities in pisoliths (Fig. 11). Secondary Au occurs as clumps and large clusters in organic C-rich zones of the cortices and cavities of pisoliths, implying a role for organic processes in their formation (Anand *et al*. 2017).

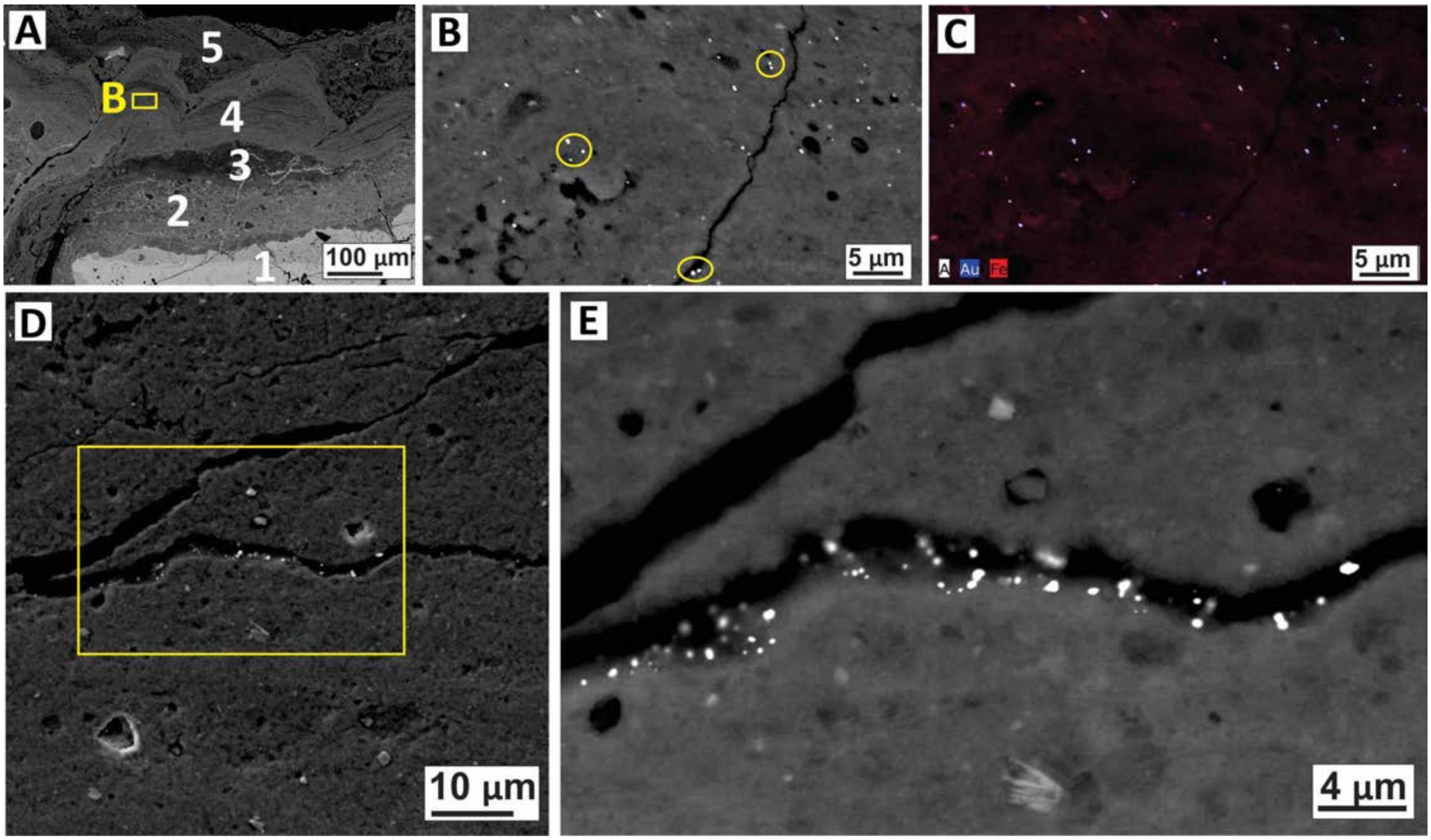


Figure 11. (A) SEM images of a sectioned pisolith from ferricrete showing hematite-rich core (1), goethite cortex (2), kaolinite cortex (3), goethite cortex (4) and goethite-kaolinite cortex (5), Mt Gibson. Boxed area in A is shown in B. (B) Multiple Au grains in goethite cortex and cavities. Some Au grains are highlighted by yellow circle. (C) Element map (EDX) of Au and Fe content of the same box shown in B. (D) Au grains in cavities of core. Boxed area in D is shown in E. (E) High magnification image of Au grains in cavity (after Anand et al. 2019).

Gold in ferricrete is sourced from mineralisation; proximally (from underlying saprolite), distally (from updrainage or from flanking valleys), or from all of these (Anand *et al*. 2017, 2019). Evolution of ferricrete gold deposits has involved several stages of mechanical, biological and chemical mobilisation and reprecipitation of Au into a palaeovalley, resulting in both high concentration of Au and large dispersion haloes. Ferricretes require significant subterranean lateral influx and migration of groundwater to transport dissolved Fe and Au along and above an unconformity, during an extended period of biological and chemical weathering. This model contrasts with the comparatively simple Au and Fe enrichment of lateritic residuum as the landscape was progressively deflated by lateritic weathering.

Garden Well and Rose Dam gold deposits (environment D5)

Garden Well and Rose Dam gold deposits provide examples of the inset-valley environment (environment D5; Figs. 2 and 4). Garden Well is a shear-hosted Archaean orogenic gold deposit. Gold mineralisation occurs as oxide ore down to 70 m below the base of the inset-valley and the hypogene ore extends to a depth of 400 m (Balkau *et al*. 2017). Primary Au mineralisation consists of a 100 m wide east dipping zone in the shear zone cutting mixed metamorphosed ultramafic rocks and metasediments extending into the eastern black shale metasediments (Balkau *et al.* 2017). Lead, Zn and Cu sulphides occur within the ore. Anomalous Au values are common in the bottom 15 m of transported cover of the inset-valley.

continued on page 18

Gold dispersion in transported cover sequences especially in… *continued from page 17*

The deposit is overlain by an inset-valley (~600 m wide that runs in a north-south direction) and is concealed by up to 35 m of transported cover (Lintern *et al*. 2013b). Above the basement derived saprolite, the base of the inset-valley transported cover sequence consists of 2-4 m of ferruginous and silicified sandstone nodules, with medium grained, angular quartz grains (the Wollubar Sandstone; physical interface; Fig. 12B,C). The nodules lack or have thin (0.5 mm) goethite coatings. A 15-20 m thick sequence of kaolinitic clays (the Perkolilli Shale) overlies the sandstone (Fig. 12C). This unit contains pisoliths (chemical interface; Fig. 12A) that commonly form <10% to 20% of the lower to middle part of the clay unit. Goethite-rich cortices form the bulk of these pisoliths. Above the pisolitic clays lies 4-6 m of megamottled kaolinitic clays. Finally, the sequence is overlain by dark red-brown ferruginous gravels and nodular red clay and calcareous to siliceous colluvium and alluvium and red brown sandy soil containing abundant polymictic clasts (Lintern *et al*. 2013b).

Both the ferruginous pisoliths and the nodules are rich in Cr, V, Co, Ni and Ti from the underlying ultramafic lithology. Laser ablation ICP-MS mapping showed that Cr (Fig. 13A), V and Ti are largely concentrated in the cores of the pisoliths with some in laminations, whereas in nodules they are uniformly distributed or occur in cracks and veins (Fig. 13E). Bulk sampling of the pisoliths show multi-element anomalies in Au (Fig. 12D; maximum 805 ppb), In (Fig. 12E; maximum 0.20 ppm), Ag (maximum 0.15 ppm), As (maximum 1340 ppm), Bi (maximum 2.9 ppm), Cu (maximum 381 ppm), Pb (maximum 162 ppm), S (maximum 1310 ppm) and Se (maximum 4.66 ppm) over mineralisation (Lintern *et al*. 2013b). These elements have significant anomaly/background contrasts, in particular for Bi, In, S and Se. Zinc (maximum 504 ppm)

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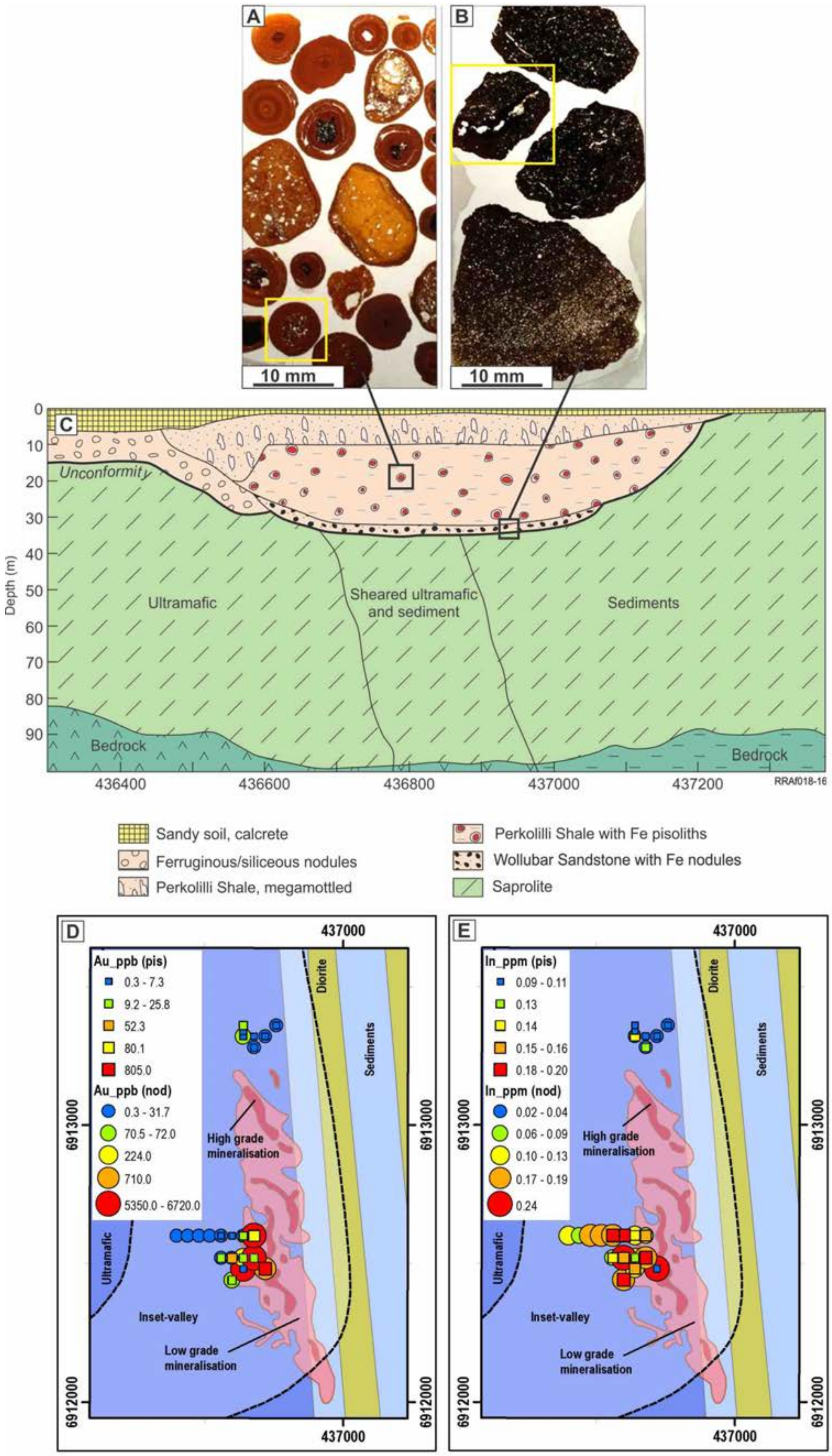

Figure 12. Photographs of (A) ferruginous pisoliths formed in inset-valley clay sequence and (B) ferruginous nodules formed at interface, Garden Well gold deposit. (C) Regolith cross section showing the stratigraphy of inset-valley transported cover. (D) Gold and In concentrations in ferruginous nodules and pisoliths relative to the location of the buried mineralisation (modified after Lintern et al. 2013b).

Gold dispersion in transported cover sequences especially in… *continued from page 18*

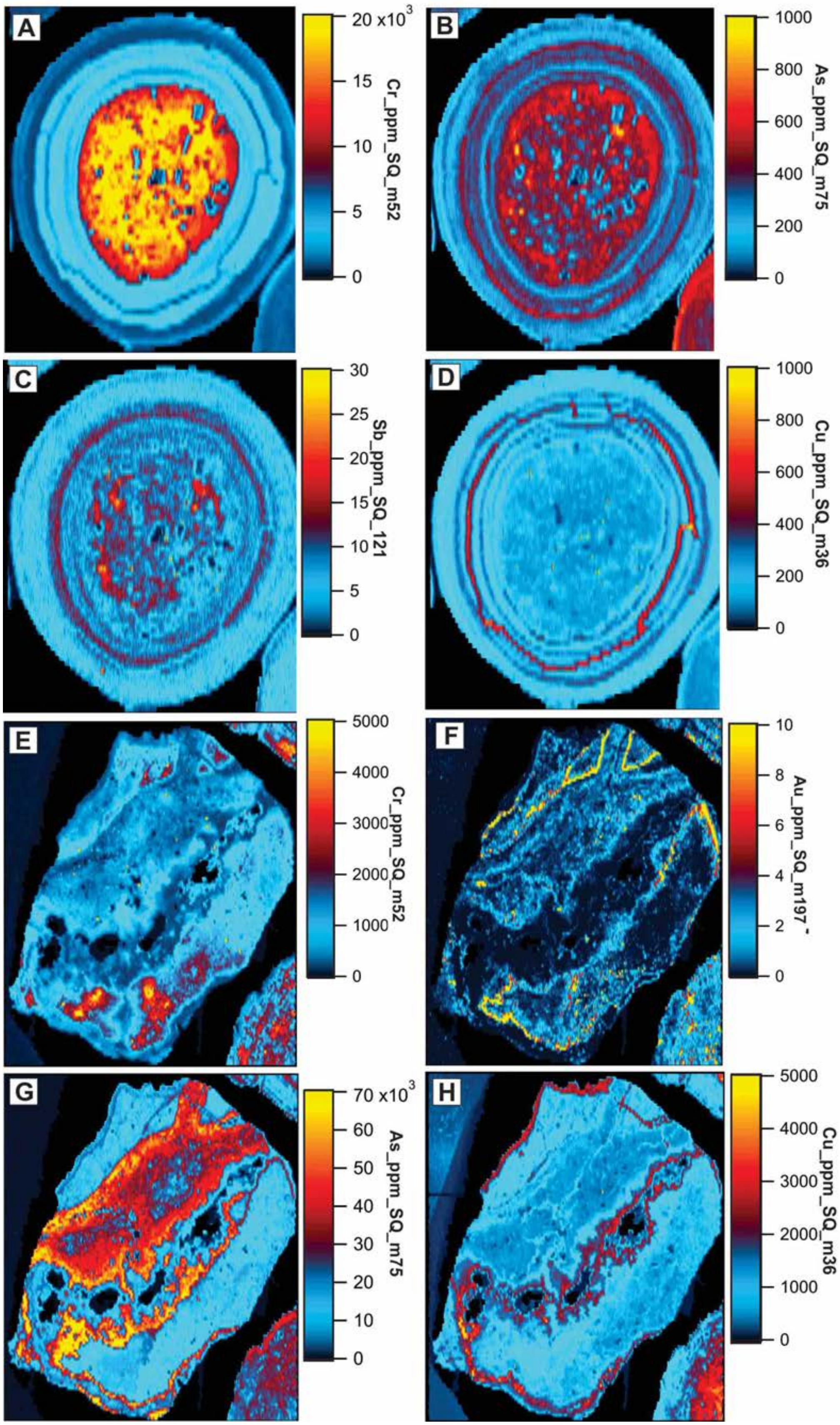

Figure 13A-D. Laser ablation ICP-MS elemental maps of a ferruginous pisolith (approximately 5 mm in diameter) shown in a yellow box in Fig. 12A; and Figure 13E-H a ferruginous nodule (approximately 10 mm in diameter) shown in a yellow box in Fig. 12B.

and Cd (maximum 0.27 ppm) are anomalous and broadly dispersed but the contrast between mineralisation and background is poor. Laser ablation ICP-MS mapping of pisoliths showed As, Cu and Sb not only occur in the core but also in laminations especially inner ones (Fig. 13B-D). Similar results were noted at the Rose Dam Gold Deposit where Cu is concentrated in cortices.

There are multi-element anomalies in nodules at the base of the inset-valley (Au (maximum 6720 ppb; Fig. 12D), In (maximum 0.24 ppm; Fig. 12E), As (maximum 5480 ppm), Bi (maximum 2.1 ppm), Cu (maximum 1741 ppm), Mo (maximum 3.6 ppm), Pb (maximum 88 ppm), S (maximum 1030 ppm), Sb (maximum 8 ppm) and Se (maximum 15. 7 ppm)). The abundances of these elements in the nodules are much greater than in the pisoliths. Visible gold was only seen in ferruginous nodules but not in pisoliths. All visible Au is micro-particulate (sizes range from 0.1 to 0.3 µm) and is confined to cavities in nodules. Authigenic Au typically contains no Ag and is secondary. Laser ablation ICP-MS mapping showed Au, As and Cu largely occur in veins and cracks (Fig. 13F-H).

There are several stages of dispersion of metals in ferruginous nodules and pisoliths of inset-valley sequence. At physical interface (the Wollubar Sandstone) there would have been physical mixing of sand with underlying anomalous weathered basement clasts that were subsequently ferruginised to quartz-goethite-hematite-rich nodules. Much of the Au in the ferruginous nodules was physically emplaced here from erosion of saprolite, followed by short-distance chemical dispersion into goethite and hematite. Strong multi-element

continued on page 20

Gold dispersion in transported cover sequences especially in… *continued from page 19*

anomalies in the Perkolilli Shale-hosted pisoliths occur in two modes, as detrital metal-rich, weathered mineralized fragments in cores or hydromorphically dispersed in goethite-rich cortical laminae. This suggests that the components of *in situ* mineralised regolith have migrated upwards into transported cover by continual redistribution during slow deposition of the clay unit. Given that the clay was most likely bioturbated during deposition, it would appear that there has been continuous interaction between the clay unit and the underlying *in situ* regolith. Bioturbation appears to be a dominant mechanism in agitating of the transported cover – an inset-valley would have supported abundant vegetation and burrowing animals.

Metal dispersion in Sequence C (transported cover deposited during arid period; Quaternary)
Calista, Bronzewing, Lawlers and Bulchina gold deposits (environment D4)

At Calista, primary mineralisation is sulphide-rich and is hosted in an overturned, steep, westerly dipping sequence of rocks. It is characterised by an association of Au, Bi, Se, Cu, Zn, Sn, W, As and Ag. At Bronzewing, gold mineralisation is associated with veins and dense stockworks of quartz within variably sheared and altered pillow metabasalts and is accompanied by pyrite, pyrrhotite, minor chalcopyrite, scheelite and visible gold. The Lawlers (North deposit) deposit lies within the Agnew supracrustal belt. Primary mineralisation occurs in quartz veins and shear zones. The Bulchina deposit is associated with quartz veining and quartz reefs. At all these sites, significant dispersion of gold and associated elements occurred into basal gravelly colluvium where it is underlain by lateritic residuum and/or ferricrete (environment D4; Figs. 2 and 4; Anand *et al*. 1989; Anand *et al.* 1993; Anand & Williamson 2000; Anand *et al*. 2001; Anand 2015). Transported cover is recent colluvium and alluvium which is about 15-20 m thick. Figure 14 shows an example from the Calista gold deposit where the dispersion of Au, Cu and As (not shown) extends from lateritic residuum to the basal gravelly colluvium and alluvium with no dispersion into soil. Examination of the size fractions of the transported cover indicates that Au is concentrated in the >2 mm fraction and is less common in the <75 m fraction, relative to the bulk sample. Hydromorphically dispersed Au would be expected to be precipitated on chemically active surfaces of Fe oxides and clays, whereas mechanical dispersion of Au would be expected to occur in ferruginous nodules and ferruginous saprolite clasts. Thus, concentration in the fine fraction would suggest mainly hydromorphic dispersion; concentration in the coarse fraction implies mechanical dispersion. Manganese nodules formed at the residual and transported cover interface show high concentrations of Cu (400-900 ppm) and Zn (200-600 ppm) but are very poor in Au (<5 ppb).

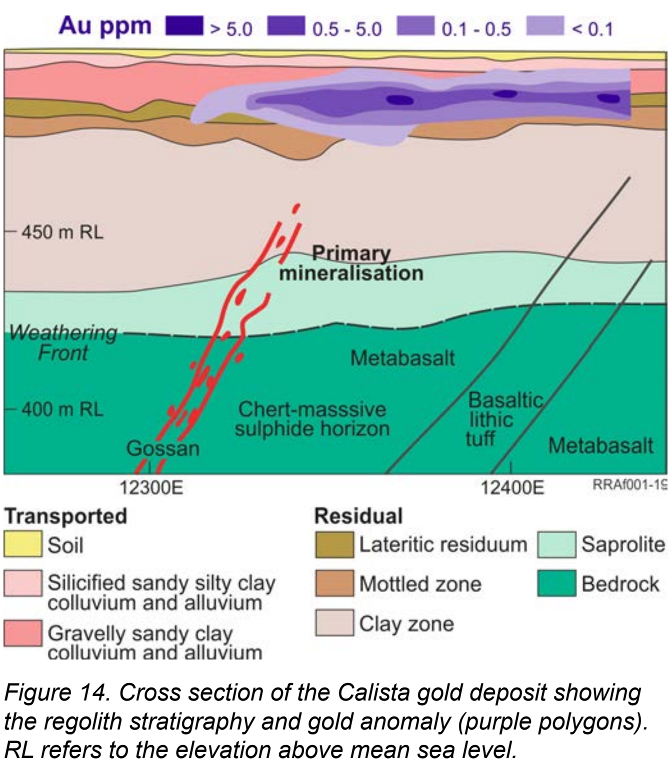

Figure 14. Cross section of the Calista gold deposit showing the regolith stratigraphy and gold anomaly (purple polygons). RL refers to the elevation above mean sea level.

Where the shallow cover (<5 m) overlies lateritic residuum or ferricrete, the whole transported cover column (except soil) can be anomalous (e.g., Moolart Well; Mt Gibson). At the Moolart Well gold deposit, the ferricrete is overlain by a widespread, silicified colluvium-alluvium (red-brown hardpan). The hardpan sampled at 1–1.5 m depth is anomalous in Au (2–350 ppb) and shows a broad halo over the ferricrete gold deposit although slightly displaced to the east. There is less Au in the hardpan than in the ferricrete, but Au is slightly enriched toward the base of the hardpan due to mixing (by bioturbation) with the upper ferricrete. This suggests that Au in the hardpan is sourced from ferricrete (Anand *et al*. 2017). Gold largely occurs as nanoparticulate spheres in the fine mass of authigenic amorphous (opaline) silica. Nanoparticulate Au spheres in amorphous Si are thought to have been deposited during a drying event after flooding (Anand *et al*. 2017).

In summary, where the transported cover is thin, bioturbation of the transported cover brings a strong anomaly close to the surface. As the transported cover thickens, bioturbation of its upper part is progressively diluted by incoming distal material until no significant anomaly remains.

Quasar, Harmony and Gruyere gold deposits (environment D6)

Gold mineralisation at Quasar is associated with ductile shearing in high Mg mafic and ultramafic metamorphic rocks. At Harmony, mineralisation is hosted within metadolerite and metabasalt. At Gruyere, mineralisation is hosted within the Gruyere Monzonite Porphyry. Gold is associated with varying intensity albite-sericite-biotite-calcite alteration of the host rock. These deposits represent significantly truncated regimes (environment D6; Figs. 2 and 4), where there is no or little locally-derived lateritic gravel. Sampling across the unconformity provided less intense but much broader geochemical

continued on page 21

Gold dispersion in transported cover sequences especially in… *continued from page 20*

targets than sampling the top of the basement. This distribution is demonstrated at Quasar, beneath 4-6 m of colluvium-alluvium (Robertson *et al*. 2001), Harmony, under 1-9 m of colluvium (Robertson *et al*. 1996) and Gruyere, under 30 m of inset-valley clays and recent colluvium-alluvium (Salama & Anand 2018b).

Pedogenic calcrete occurs mainly in the Southern region of the Yilgarn Craton, south of the Menzies Line. Gold can be enriched in carbonate horizons of soils and may give rise to, or enhance, a near-surface expression of concealed primary or secondary mineralisation (Lintern 2015). The distribution of Au is very closely correlated with Ca carbonate, commonly in the top 1–2 m of the soil; the chemical, and biogeochemical, processes involved may give surface expression even to mineralisation concealed by up to 8–10 m of transported cover.

Discussion and conclusions

Several types and ages of transported cover may overlie an *in situ* weathered profile. The interplay between Permian, Tertiary and Quaternary sedimentation and weathering have led in some places to multiple profiles, a feature described in the voluminous literature on palaeosols (Kraus, 1999). The nature and evolution of transported cover strongly influence the effectiveness of metal transfer. Mechanisms that are relevant in older (Permian, Sequence A; Eocene-Miocene, Sequence B) transported cover and climatic setting with high water tables are not relevant in Quaternary cover sequence under dry conditions. Thus, understanding the landscape history is essential to understanding the mechanisms of metal transfer and to selecting appropriate sampling media and interpreting the data.

There have been several stages of Au mobilisation in transported cover sequences. In older transported cover (Sequences A and B), in addition to mechanical dispersion, groundwater-related solubilisation and subsequent deposition of Au and pathfinder elements can form anomalies especially in Fe oxides (palaeoredox fronts) within the weathered cover at or below surface. These palaeoredox fronts occur as goethite-hematite-rich ferruginous nodules and pisoliths that are formed during the Palaeocene and more commonly Mid to Late Miocene under seasonal climatic conditions. In past saturated environments, the dispersion occurred by developing a redox gradient between the water table and buried sulphide mineralisation as proposed for electrochemical models (Govett 1976; Smee 1983; Hamilton 2000). Furthermore, the formation of stacked weathering profiles in distinct transported cover units favoured the transfer of metals across each weathering profile by bioturbation.

Although water and its dissolved constituents typically flow down-gradient, subsurface mineralised water can be transferred to the surface through faults by seismic or dilatancy pumping (Sibson *et al*. 1975). Compressional stresses along faults arising from earth tremors force the mineralised groundwaters upward, with possible surface discharge of water and their rapid evaporation resulting in near-surface anomalies (Cameron *et al*. 2002; Kelley *et al*. 2003). This is limited to low-rainfall and neo-tectonic areas that have regular seismic activity. Geochemical dispersion along ferruginised joints and fractures has been observed in the Mt Isa region of Northern Queensland (Lawrance 1999; Anand 2016; Salama *et al*. 2016b). For example, at the Osborne Cu-Au deposit where the Mesozoic transported cover is strongly faulted and fractured, the geochemical expression from the ore occurred preferentially through discrete sub-vertical fractures (Lawrance 1999; Rutherford *et al*. 2005). The country rock and palaeoredox zones host low-order anomalies close to the vertical fractures or where the redox fronts intersect the ore. However, it is not certain how much a role this mechanism has played in forming anomalies at the sites studied in Western Australia. Weathered basement at the sites investigated are commonly faulted and fractured but no vertical fractures formed by reactivation of basement faults were observed in the overlying transported cover. However, mottled, cross-laminated sandstones and siltstones with a variety of dissolution features such as dissolution-collapse brecciation are noted in the Permian cover. It is not clear whether these features are related to weathering or preferentially developed over the ore body.

The change from ferruginisation to silicification and calcification weathering is consistent with a significant decrease in rainfall and the onset of the modern dry climate. Over time, in response to this drier climate, the water table has gradually dropped to its current low position commonly between 20-30 m below surface. The association of Au with pedogenic calcrete and siliceous hardpan in Quaternary transported cover (Sequence C) indicates that movement of Au is still active. Palaeoredox fronts are not developed in recent transported cover as they were deposited when the water tables were much lower in this arid period. Mechanical with some chemical dispersion mainly occurs in the basal cover. Where it occurs, pedogenic calcrete formed in colluvium and alluvium may show an expression of mineralisation concealed by up to 10 m of transported cover. The role of plants has been demonstrated in forming anomalies in calcrete (Lintern 2015).

Our research has shown that study by microscopic analysis and micro-geochemical mapping of indicator elements in cover materials has revealed some of the mechanisms of geochemical dispersion and so indicate optimal geochemical sampling media. In older transported cover, ferruginous nodules and pisoliths and/or an unconformity between the transported cover and the underlying rock are preferred sample media. In recent transported cover, sampling of basal gravelly sediments and along the unconformity is optimal. Where it occurs, the calcrete horizon is the preferred near-surface sample medium for Au exploration, except where residual ferruginous materials are present. No other ore-related elements show this association with calcrete. More studies are needed to further identify regolith materials and minerals

continued on page 22

Gold dispersion in transported cover sequences especially in…

continued from page 21

that might act as deep geochemical sensors of buried deposits and further provide optimal exploration sampling media for areas of deep cover.

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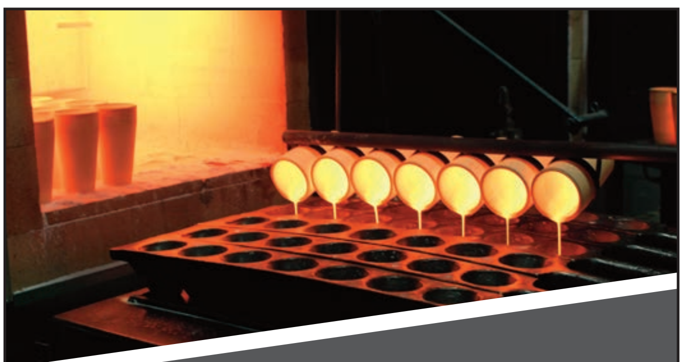

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continued on page 24

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New AAG Reginal Councillor for Mexico

Tomas Grijalva is the new AAG Regional Councillor for Mexico. He is an assistant manager of the Mexican Geological Survey with responsibility for the geochemical aspects of uranium, thorium and rare earth elements in the country, since his Ph.D. (Universidad Nacional Autónoma de México-UNAM, Mexico); he has been dedicated in the geochemistry mobility and speciation of those elements, employing *in situ*, laboratory (conventional) and nuclear techniques. He was involved in the Carbon Capture Sequestration Mexican Initiative, fulfilling the geochemical aspects of CO_2 interaction with water and rocks, among others studies related with hydrogeochemistry, environmental geochemistry and medical geology with different research groups and companies. His research interests include water, uranium, thorium, and rare earth geochemistry, also geostatistics and un/supervised machine learning applications in applied geochemistry.

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Gerry Govett

The AAG was sad to hear of the death of one of our best known members, Gerry Govett, in January, 2019. Gerry was a founding member of the Association of Applied Geochemists (formerly the Association of Exploration Geochemists), President of the Association from 1976 to 1977, and recipient of the AAG Gold Medal in 2009. Gerry was a major contributor to the development of the Association, including the transition to the new name and broadening of its scope.

Gerry was born in Sully in Wales. He was baptised Gerald James Spurgeon Govett. His third name acknowledged his mother's high regard for that illustrious 19th Century evangelist, and which would subsequently be reflected in Gerry's equally keen commitment to research and teaching.

Gerry completed his first degree the University of Wales followed by a PhD at Imperial College London working on geochemical exploration for copper in Northern Rhodesia (now Zambia). After seven years with the Research Council of Alberta following completion of his PhD, Gerry headed off to academia where he would spend the next 30 years, commencing with the University of the Philippines (1965) and continuing onto the University of New Brunswick (1966-1976) and finally the University of New South Wales (1977-96). Shortly after arriving at UNSW, Gerry was appointed Head of the School of Applied Geology, attracting a number of graduate students into exploration geochemical research. He was appointed Dean of the Faculty of Applied Science in 1983 and continued as a highly respected academic leader in that role until that faculty was disestablished as all the sciences at UNSW commenced condensation into a single Science Faculty. He would meet his future wife, Idelies, at UNSW.

During his academic career, Gerry was also involved as a consultant geochemist for the United Nations Development Programme, a member of the Canadian Geoscience Council, a visitor to the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), a number of national or international scientific panels and scientific projects, and President of the Australian Geoscience Council (1983-84). He was also involved in the corporate sector, including a period as Chair of Delta Gold Ltd. He was regularly called upon for advice by various geological surveys around the world, and was on the editorial boards of a number of journals. Gerry was a great colleague, mentor and very supportive supervisor to many other geologists and geochemists. His list of co-authors and students is a veritable Who's Who of the exploration geochemical world from the 1960s to the 1990s. A long-term and fiercely loyal support staff was testament to his integrity and personal qualities. His perspective on a wide range of both educational and mining industry issues was often sought and readily given. His dry sense of humour and calm manner was much appreciated by colleagues and students.

He was a meticulous scientist and a very engaging writer, though debates with students on the nuances of punctuation and grammar sometimes rivalled some scientific arguments. He commenced a number of lithogeochemical studies in eastern Australia and co-authored one of the earliest papers on electro-geochemical dispersion through cover.

Though his contribution in many aspects of exploration geochemistry and other aspects of geology is evident in his string of highly cited papers, his most enduring legacy is probably the landmark Handbook of Exploration Geochemistry, whose seven volumes Gerry edited and, in the case of Volume 3 on lithogeochemistry, contributed much of the content. Gerry was on the board of CRC LEME as well as exploration companies.

Gerry moved in later years to the NSW southern highlands where he continued to pursue some economic geology interests as well as turning his hand to olive growing, and continued to attend IAGS. Gerry will be sorely missed by the exploration geochemical community and we extend our condolences to Idelies and others of Gerry's family.

To donate the AAG's Distinguished Applied Geochemists Fund in Gerry's honour, go to: https://www.appliedgeochemists.org/association/distinguished-applied-geochemists-fund

David Cohen
On behalf of many of his colleagues and former students

Thomas (Tom) Edward Lane

July 12, 1947 - March 18, 2019

Tom in the field

Thomas "Tom" Edward Lane, Ph.D., P.Geo. died on March 18, 2019. He was born in 1947 in Lancaster County, Pennsylvania, USA and he received his early education in schools (and every hill and stream) in Delaware County in Pennsylvania. He was granted degrees in geology or earth sciences from Franklin and Marshall College, Dalhousie University, and Memorial University of Newfoundland.

He spent over 25 years employed by Teck Corporation's exploration division in Newfoundland and Toronto in various roles including that of Senior Research Geologist before becoming in 2003 the Director, Research Development, Exploration Division of the Canadian Mineral Industry Research Organization (CAMIRO), an organization created to initiate, manage and disseminate scientific research by university researchers on real world problems and topics confronting and therefore funded by the mining industry. He developed and directed over 25 CAMIRO projects, many of which championed the development and understanding of innovative technology in exploration, and the training of geoscientists and applying geoscience, including geophysical and geochemical techniques, to mineral exploration and metallurgical processing.

As an adjunct professor in the Department of Earth Sciences at Laurentian University, Sudbury, Canada since 1996, Tom provided lectures, supervised graduate students, and organized workshops while serving on the advisory board of the Mineral Exploration Research Centre (MERC), most recently as Chair. Tom co-authored a seminal paper on the state of Canada's mineral exploration industry in 2010 that was instrumental in the subsequent creation of the Canadian Mining Innovation Council (CMIC) Exploration Innovation Consortium (EIC) Footprints Project, an industry-led initiative to formulate and guide the mineral exploration strategy for different deposit types across multiple disciplines and funded by NSERC, Canada's national scientific research body.

The Canadian Institute of Mining, Metallurgy and Petroleum (CIM) awarded him the A.O. Dufresne Exploration Achievement Award in 2015 in recognition of "exceptional achievements or distinguished contributions to mining exploration in Canada", which included his important contributions to understanding the genesis of, and therefore methods to exploration for Zn deposits at Teck Corporation's mine near Daniels Harbour in western Newfoundland. Tom was invited to contribute to EU funded 2018-2020 project Innovative Non-Invasive & Fully Acceptable Exploration Technology (INFACT). He provided consulting services to several mining exploration companies during his time with CAMIRO. He served as Councillor for the Geological Association of Canada amongst numerous other volunteer tasks in local and national geologic organizations. He is described by one colleague at Laurentian as "one of the most dedicated people that I have ever worked with". A session at the recent meeting of the Geological Association of Canada in Quebec City in May 2019 was named in his honour to celebrate Tom's contributions to the Canadian geological community.

Geology and the natural world were Tom's vocation and avocation. He was driven by his curiosity. Tom had a passion for knowledge of all things natural, especially but not limited to birding. He had little interest in the material world - family, friends, work, nature and art fulfilled him. He was a gifted teacher who patiently passed along his encyclopedic knowledge to colleagues and students, indeed, to anyone who expressed an interest. In addition to spirited discussions on geological field trips and chance and planned encounters at conventions, conferences and symposia, special memories that his wide circle of friends will treasure include passing time together patiently at birding vigils, attending basketball, baseball and hockey games in Toronto, enjoying live performances of jazz, folk, rock and blues music in St. John's and elsewhere, exploring art exhibitions and attending movies during TIFF. A friend recalls a recent conversation with Tom where they mused about him being the naturalist on an Antarctic cruise ship when he retired - this would have been a perfect fit, both for him and the lucky fellow passengers.

Tom was a faithful friend to those whose lives he entered, and he never lost an opportunity to overcome distance to maintain a friendship. His gentle nature and unpretentious ways endeared him to an unusually broad spectrum of society, and in turn, he was equally at home in the boardroom, a university setting, or a fisherman's kitchen in rural Newfoundland. In addition to his vast knowledge across many disciplines, few will forget his smile, giggle and sense of humour.

Donations in his honour may be directed to charitable organizations that promote science and our understanding of the natural world. To donate the AAG's Distinguished Applied Geochemists Fund go to: https://www.appliedgeochemists.org/association/distinguished-applied-geochemists-fund

Lunch on Ospwagan Lake, Thompson Ni Belt

Modified from:
https://mountpleasantgroup.permavita.com/site/ThomasTomEdwardLane.html?s=110

AAG Councillor Elections for the Term 2020-2021

Each year the Association of Applied Geochemists (AAG) needs motivated and energetic AAG Fellows to stand for election to the position of “Ordinary Councillor.” Fortunately, each year some of our most outstanding Fellows are ready, willing, and able to meet this challenge. However, this year I’m sending this to **ALL MEMBERS**, to encourage those Members that have the experience and enthusiasm to be involved, to convert your membership status and look to make a bigger contribution to the AAG (see the website for details).

This note is the annual reminder to AAG Fellows (and Members that could become Fellows) that we need your participation on Council. It is our sincere hope that this email might entice more people to step forward for election to this important position. If you are not eligible to become a Fellow, but want to be more involved, please send me an email message as we are looking to get more of our junior members active in the AAG and other opportunities will be coming available.

Councillor Job Description

The AAG By-laws state that “the affairs of the Association shall be managed by its board of directors, to be known as its Council.” The affairs managed by Council vary from reviewing and ranking proposals to host our biennial Symposium to approving application for new membership to developing marketing strategies for sustaining and growing our membership. These affairs are discussed and decisions made at Council teleconferences usually held 3-4 times per year. Each teleconference lasts about 1 hour. In addition, there is often a running email discussion about a selected issue or two between each teleconference. So for a commitment of about 5 hours of your time per year, you can help influence the future of your Association. If you want to spend more than the minimum time required, there is plenty of opportunity to do so through committee assignments and voluntary efforts that greatly benefit the Association.

Qualifications and length of term

The only qualification for serving as Councillor is to be a Fellow in good standing with the Association. Please note the difference between being a Member of AAG and being a Fellow. A Fellow is required to have more training and professional experience than a Member. Consult the AAG web site, Membership section, for further details. If you are not currently a Fellow and have an interest in serving on Council, please go through the relatively painless process of converting to Fellowship status in AAG.

Each Councillor serves a term of two years and can then stand for election to a second two-year term. The By-laws forbid serving more than two consecutive terms, although someone who has served two consecutive terms can stand for election again after sitting out for at least one year. Elections are usually held in Octber-November of the year for a term covering the following two years. Our next election will be in October-November 2018 for the term of 2019-2020.

How to get on the ballot

If you are interested in placing your name into consideration for election to AAG Council, simply express your interest to the AAG Secretary (Dave Smith, email: dsmith@usgs.gov) by **October 15, 2019** and include a short paragraph (no more than 250 words) summarizing your career experience. This summary should include the following:

- Your name
- Year that you became a Fellow of AAG
- Earth science degrees obtained, year of graduation of each, and institution of each
- Employment—list major employers and state years worked for each, e.g. 1980-1990, and type of work
- Position(s) held as part of AAG or other past contributions to AAG
- 1-2 sentences about your professional experiences in applied geochemistry

All that is asked is that you bring energy and ideas to Council and are willing to share in making decisions that will carry the Association forward into a successful future. We look forward to hearing from you.

Steve Cook
President, Association of Applied Geochemists
Email: Stephen_Cook@telus.net

29^{th} International Applied Geochemistry Symposium
EXPERIENCE CHILE
Facing the Challenges of Today Using Applied Geochemistry

On behalf of the Organizing Committee, we invite you to take part in the 29^{th} International Applied Geochemistry Symposium which will be held in Viña del Mar, Chile, from November 8 to 13, 2020. The Symposium is sponsored by the Association of Applied Geochemists (AAG) in collaboration with the Sociedad Geológica de Chile (SGCh). It is organized by local representatives of both associations .All information concerning the venue, program, accommodation and events can be found on the Symposium website: http://www.iags2020.cl

Symposium Venue

The venue for IAGS 2020 is the historical Hotel O'Higgins in the City of Viña del Mar, which is also known as "The Garden City". Viña del Mar is 120 km northwest of the capital city of Chile, Santiago. It is a well-known tourist destination, famous for its beaches, the neighboring world heritage city of Valparaiso and abundant parks, as well as nearby famous vineyards in the Casablanca Valley to the east and the San Antonio Valley to the south. The Hotel O'Higgins is a landmark that was built in 1931 and is located in the central part of the city.

Scientific Program

The Scientific Program consists of oral and poster presentations over four days, November 9-10 and 12-13. Oral presentations will be divided into plenary (40 minutes) and general technical sessions (20 minutes). Poster presentations will be on-going throughout the Symposium, including networking sessions during the early evenings.

Proposed technical session themes

- Exploration geochemistry: present and future challenges.
- New field portable technologies: improving analysis and turnaround time in exploration.
- Big data: squeezing multi-element geochemical data by means of data science and self-learning techniques.
- Geochemistry applied to mineral characterization for geological, geometallurgical and resource modeling.
- Environmental geochemistry: closing the gap for sustainable mining and development.
- Water and hydrogeochemistry: challenges in exploration, mining and sustainable development.
- Isotopic geochemistry: new uses in applied geochemistry.
- Geochemistry of the critical zone: linking geology to viticulture and wine.
- Analytical geochemistry technologies and quality assurance / quality control.

Workshops

Pre-symposium workshops planned for November 6 to 8:

- Fundamentals of geochemical exploration methods
- Quality Control / Quality Assurance.
- Field portable geochemistry (XRF, LIBS): applications and limitations.
- Data science in geochemistry: from exploration to geometallurgy.

continued on page 29

29th International Applied Geochemistry Symposium… *continued from page 28*

- Geology, mineralogy and geochemistry in viticulture.
- Geology and metallogenesis of Chile.

Field Trips

The following Post-symposium field trips are planned for November 14 to 20:

- Mineral deposits of northern Chile (5 days).
- Geological and metallogenic evolution of central Chile: The Andean transect (5 days).
- Geology and Vineyards of central Chile: Geochemistry of the critical zone (3 days).
- Polluted areas of central Chile: Detecting the issues (2 days).

Social Program

The social program will provide an opportunity to greet old friends and build new networks in a comfortable and friendly environment, and it will allow attendees to experience the unique Chilean culture and beautiful landscape of the Valparaiso Region.

- **Ice breaker**: Outdoor pool area of Hotel O'Higgins, November 8
- **Pub crawl**: Enjoy nightlife in downtown Viña del Mar, November 9.
- **Wines of Casablanca**: Vineyard day tour, wine tasting, lunch and a taste of Chilean culture on a day tour to *Estancia El Cuadro*. November 11.
- **Symposium AAG Gala Dinner**: AAG traditional gala dinner by the coast, Nov. 12.
- **Wine and beer**: During poster sessions, early evening wine and beer, Nov. 9, 10, 12.
- **Closing ceremony**: November 13.

Accompanying person activities

- November 9. Visit the historical city of Valparaiso and tour down the central coast.
- November 10. Vineyards of Casablanca and San Antonio valleys.
- November 12. Cajón del Maipo tour – into the Andes.
- November 13. Tour of the Viña del Mar Botanical Gardens and museums.

Important Dates

- On-line registration opens June 1st, 2019
- Abstract submission begins September 1st, 2019
- Deadline for abstract submission March 31st, 2020
- Early bird registration June 30th, 2020
- Abstract review and decisions May 31st, 2020
- Pre-symposium field trip registration April 30th, 2020
- Post-symposium workshop registration April 30, 2020

Student Prizes

Prizes for student presentations will include the best oral paper (**the SGS-AAG prize**) and other oral (2nd and 3rd places) and poster presentations (1st, 2nd and 3$^{rd)}$. Sponsorship for various student prizes is available.

Registration

On-line registration for the Symposium will open in June 2019. Registration will be required prior to submitting abstracts or intention to attend the workshops and/or field trips.

Symposium Fees

There will be four categories of delegate fees for attendance at IAGS 2020:

- AAG or SGCh delegate:
  - Registered member of the Association of Applied Geochemist (AAG); and/or
  - Registered member of the Chilean Geological Society (SGCh)
- Non-member of AAG or SGCh delegate
- Student from an undergraduate or graduate program at the time of registration
- Accompanying person, such as a spouse or partner

continued on page 30

29th International Applied Geochemistry Symposium… *continued from page 29*

Category	Date	Registration Fee ($US)
Early bird – AAG / SGCH delegate	Until June 30, 2020	620
Early bird – non delegate	Until June 30, 2020	740
Early bird – Student	Until June 30, 2020	280
Standard – AAG / SGCH delegate	After June 30, 2020	700
Standard – non delegate	After June 30, 2020	820
Standard – Student	After June 30, 2020	320
Accompanying Person	Until October 31, 2020	120

The fees for delegates includes attendance at the opening, closing and all technical sessions, the welcome reception (ice breaker), coffee breaks, lunch, complementary evening wine and beer, a symposium kit and electronic certificate of attendance. The registrations for accompanying persons include attendance at the opening, closing and welcome reception (ice breaker).

The costs for Symposium AAG Gala Dinner, pre-symposium workshops, post-symposium field trips, and social activities not specified above and the accompanying person activities are not included in the registration fee. These costs will be included in the second circular.

Accommodation

Viña del Mar hosts a number of attractive accommodation options. The Symposium venue is located close to the Municipality of Viña del Mar and there are various other accommodations, including many hotels of various categories, low cost hostels as well as ample offers for apartment rentals (e.g. Airbnb), all of which are in the near vicinity of Hotel O'Higgins. An attractive rate has been arranged with Hotel O'Higgins.

Travel

All international flights to Chile arrive/depart to/from the International Airport "Arturo Merino Benitez" in Santiago, the capital of Chile. Attendees can easily obtain bus transport to Viña del Mar from Santiago's airport.This bus ride from Pajaritos to Viña del Mar is approximately 1 hour and 30 minutes. The bus terminal in Viña del Mar is walking distance from Hotel O'Higgins. Apart from buses, private taxis or shuttles are available at the airport in addition to rental cars from most major providers. From the Santiago Airport, the drive to Viña del Mar is approximately 1 hour and 30 minutes via Route 68.

Passport and visa requirements

All overseas visitors are required to have a valid passport (with at least six months remaining) for the duration of stay in Chile. With the exception of delegates from visa-free countries, attendees are required to have the appropriate visa. In the simplest case, foreigners that enter the country with a valid passport will be granted a tourist visa which will last for 90 days. Depending on the nationality of the attendee, the tourist visa may have a fee (e.g. Australia and Canada). For more information, please consult the following website: https://chile.gob.cl/chile/blog/todos/tourist-visa. It also contains a link to a spreadsheet regarding the tourist visa and any related cost which will depend on the nationality of the attendee. Visas may also be obtained before departure from offices of the Chilean Embassy or Consulate in the attendee's home country.

Language

Spanish is the official language of Chile, however English will be the official language of IAGS 2020.

continued on page 31

29th International Applied Geochemistry Symposium… *continued from page 30*

Currency, banks and credit cards

The unit of currency in Chile is the Chilean Peso (CLP). Money exchange facilities are available on arrival to the Arturo Merino Benítez International Airport and also at banks. Additionally, currency exchange facilities can be found in all major cities of Chile.

All purchases in Chile are subject to a 19% tax. This is usually included in the published retail prices for all goods and services. In restaurants and bars, the usual service fee (tip) is 10% and it can occasionally be requested in cash.

Banks are open Monday through Friday from 9.00 am to 2.00 pm. Automatic teller machines (ATMs) are common and functional at all hours. They accept most foreign credit and debit cards which are authorized to be used in a foreign country (it is recommended to notify your bank before trip to Chile, so that credit and debit cards can be used without any restrictions in the country). In addition, most stores will accept foreign credit cards (Visa and Mastercard) provided that authorization has been granted by the visitor's foreign bank for use of that credit card in Chile.

Weather

The weather in Viña del Mar is a Mediterranean type with oceanic influence, foggy skies, warm summers and rainy winters. The climate in this area is influenced by the Humboldt ocean current, allowing for a mild climate with pleasant temperatures throughout the year, similar to Valparaíso. In November, the month of 29th IAGS2020, the average and minimum temperatures are 22°C (71 F) and 15°C (59 F), respectively.

Organization

The Local Organizing Committee (LOC) consists of:

- President: **Dr. Brian Townley**, Associate Professor and Sub Director, Department of Geology, University of Chile.
- Vice President: **Dr. Joseline Tapia**, National Director of Geology, Universidad Santo Tomás.
- Committee Members:

    Dr. Pamela Castillo, Universidad de Chile
    Dr. Paula Ramírez, WSP
    Fernando López, **MSc.,** GeoAV
    Sofía López, **MSc.,** ICASS
    Germán Ojeda, **MSc.,** Antofagasta Minerals
    Carolina Soto, **MSc.,** WSP
    Dr. Peter Winterburn, Vale

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MERC
MINERAL EXPLORATION RESEARCH CENTRE

Department of Earth Sciences/Département des Sciences de la Terre
Ottawa ON Canada K1N 6N5

The Department of Earth and Environmental Sciences at the University of Ottawa, the Mineral Exploration Research Centre at Laurentian University, and the Goldcorp Chair in Economic Geology are pleased to announce the *2019 Joint Modular Course on the Geochemistry of Hydrothermal Ore Deposits*:

MINERAL-CHEMICAL MODELS OF ORE FORMATION

The course will be held at the University of Ottawa between October 12 and 19 and will feature four 2-day modules to be presented by Dr. Mark Hannington (University of Ottawa), Dr. Matthew Leybourne (Queen's University), Dr. Daniel J. Kontak (Laurentian University), and Dr. J. Bruce Gemmell (University of Tasmania).

Oct 12 & 13 A Practical Guide to the Ore Elements, Minerals and Fluids
Oct 14 & 15 Analyzing Rocks, Minerals and Fluids in Hydrothermal Systems
Oct 16 & 17 Fluid-Rock Interaction and Processes of Hydrothermal Alteration
Oct 18 & 19 Case Studies: Magmatic-Hydrothermal and Seawater-Dominated Systems

Alteration mapping and pathfinder element geochemistry continue to be basic tools in exploration for ore deposits. A solid understanding of mineral chemistry and mineral-chemical systems underpins nearly every successful application of these tools. This intensive 8-day course will explore the fundamentals of mineral-chemical systems in hydrothermal ore deposits, including practical aspects of ore element geochemistry, alteration mineral assemblages, water-rock interactions and the techniques to recognize them. The course will provide an introduction to concepts that are critical to that understanding, including mineral stabilities and controls on metal solubility in hydrothermal systems, P-T-pH-redox conditions and their importance in ore formation and alteration and the integration of basic field and laboratory analyses to unravel these processes. Participants will receive instruction and hands-on experience in the acquisition and analysis of mineral-chemical data relevant to a wide range of hydrothermal systems, and they will explore case studies developed for some of the world's most important ore deposit types … "from drill core to the laboratory and back".

The course is open to graduate students from any university as well as professionals in industry. Credit transfer toward degree programs is possible for Ontario students, and industry participants may receive credit for professional training requirements.

Registration forms and a detailed course description can be requested from icsr@uottawa.ca:

Early registration ends August 21, 2019

Fees for students will be $200 for the full course ($300 after August 21). Fees for professional participants are $500 per 2-day session. For further information, please contact:
icsr@uottawa.ca

Welcome New AAG Members 2019

Fellows

Fellows *are voting members of the Association and are actively engaged in the field of applied geochemistry. They are nominated to be a Fellow by an established Fellow of the Association by completing the Nominating Sponsor's Form.*

Dr. Pim van Geffen
Principal Geochemist
Vancouver Geochemistry
769 Keefer St,
Vancouver, BC
Canada, V6A 1Y6
Membership # 3917

Dr. Tomas Grijalva Rodriguez
Servicio Geologico Mexicano
Lopez Del Castillo No. 14
Col. Olivares
Hermosillo
Mexico SON 83180
Membership # 4403

Members

Members *are non-voting members of the Association and are actively engaged in the field of applied geochemistry at the time of their application and for at least two years prior to the date of joining.*

Dr. John Chapman
Rio Tinto
Presidente Riesco 5435
Oficina 1302
Las Condes, Region Metropolitana
Chile 7561127
Membership #4401

Dr. Samuel Weatherley
Teck Resources Ltd
Suite 3300, Bentall 5
550 Burrard St.
Vancouver BC
Canada V6C 0B3
Membership # 4402

Dr. Tomas Grijalva Rodriguez
Servicio Geologico Mexicano
Lopez Del Castillo No. 14
Col. Olivares
Hermosillo
Mexico SON 83180
Membership # 4403

Jessica Quintanilla
Edwards Aquifer Authority
900 E Quincy
San Antonio TX
United States 78215
Membership # 4404

Mr. Taotao Yan
Geochemist
Institute of Geochemical and Geophysical Exploration
84 Jinguang Road
Langfang Shi
Hebei Sheng
CHINA 065000
Membership # 4406

Mr. Mi Tian
Geochemist
Institute of Geochemical and Geophysical Exploration
84 Jinguang Road
Langfang Shi
Hebei Sheng
CHINA 065000
Membership # 4407

Dr. Ben Cave
Project Geologist
Independence Group (IGO)
South Shore Centre, Suite 4
Level 5/85 S Perth Esplanade
South Perth, WA
AUSTRALIA 6151
Membership # 4408

Student Members

Student Members are students that are enrolled in an approved course of instruction or training in a field of pure or applied science at a recognized institution. Student members pay minimal membership fees.

Mr. David Kaeter
PhD Candidate
Irish Centre for Research in Applied Sciences
School of Earth Sciences
University College Dublin
Belfield, Dublin
Ireland Dublin4
Membership # 4400

Bridging the gap between exploration and geochemistry: University of Freiburg's Exploration Geology short course

An excited and enthusiastic atmosphere filled the building's foyer on the first day of the University of Freiburg's short course in Exploration Geology held between March 18-21, 2019 at the Institute of Earth and Environmental Sciences, University of Freiburg, Germany. Participants from both academia and industry were present and represented at least fifteen different nationalities providing an excellent atmosphere for networking and socializing. The course was fully booked, as prof. David Dolejs, Dr. Katerina Schlöglová, Dr. Denis Schlatter, and Dr. Malte Junge conducted a well-organized and comprehensive schedule maximizing the benefit for participants.

Simply titled, "Exploration Geology," it quickly became apparent that the short course would exceed expectations with a plethora of useful tools, strategies, applications, and context covered during three days, with content that bridged several disciplines, including geochemistry for mineral exploration. Lectures on geochemical sampling and considerations, quality control, and geostatistics were given, followed by practical sessions requiring the evaluation and visualization of large geochemical datasets. The use of geochemical software GCDkit and ioGAS was led by Katerina Schlöglová, while David Dolejs conducted hands-on methodical management and interpretation of the data. Through the use of classification diagrams and fundamental petrological logic, trends in datasets developed and key information about ore and host rocks was revealed. A series of case-study-based lectures by Denis Schlatter, as well as an ore microscopy lab tutorial given by Malte Junge, reminded participants of the importance of geological observation before geochemical interpretation.

In addition to 3 days of comprehensive lectures, the coffee breaks and social activities provided opportunities for discussion and networking, including an informal poster session in which participants and

continued on page 35

Bridging the gap between exploration and geochemistry… *continued from page 34*

lecturers shared their ongoing research. Furthermore, a course dinner allowed participants to socialize with each other while experiencing traditional German cuisine. Networking continued during the following one-day field excursion. We traveled to the near-by Schwarzwald to visit the upper Rhine Graben-related Pb-Ag-fluorite-barite mineralization including Badenweiler mine dump and Finstergrund underground mine. Both insightful and practical, the trip allowed participants to reinforce the principles learned about lithogeochemical work through implementation of field geology. A spectacular visit to the Orberg carbonatite in the Kaiserstuhl magmatic complex gave participants a unique outcrop with which to conclude the trip, together with a "*stein and wine*" experience at a local winery.

As a PhD student in economic geology interested in exploration and geochemical application, the course offered an abundance of advantageous information to be used in practice and theory. Consensus from the participants indicated that the course exceeded expectations with some suggesting to extend it for more days! The enthusiasm from all participants illustrates why this course continues to receive high reviews and recommendations from industry and academia alike.

Leslie Logan
Lulea University of Technology, Sweden

Current Status of Applied Geochemistry Research in Europe

The **EuroGeoSurveys Geochemistry Expert Group** (which has succeeded the WEGS and FOREGS Geochemistry Working Groups) is very active in continental-scale applied geochemical projects. Since the publication of the FOREGS Geochemical Atlas of Europe (http://weppi.gtk.fi/publ/foregsatlas/), the group has completed another two continental-scale projects. The first is concerned with European ground water geochemistry using bottled mineral water as the sampling medium (Reimann and Birke, 2010; Birke et al., 2010). This special issue includes 15 contributions from national teams in Croatia, Serbia, Slovenia (2), Hellas (2), Slovakia, Hungary, Italy (2), Fennoscandia, Germany (2), Portugal and Estonia. The second continental-scale project, completed in 2014, is concerned with the Geochemistry of European Agricultural and Grazing Land Soil (GEMAS – URL: http://gemas.geolba.ac.at/)and resulted in the publication of a two-volume atlas (Reimann *et al*., 2014a, b). The atlas on the geochemistry of agricultural and grazing land soil reports data for 68 determinands covering almost the entire European territory west of the Urals.

Apart from the completed continental-scale projects, the European Geochemistry Expert Group carries out urban geochemistry projects and published a textbook in 2011 (Johnson, C.C., Demetriades, A., Locutura, J. & Ottesen, R.T. (Editors), 2011. *Mapping the Chemical Environment of Urban Areas*. Wiley-Blackwell, Oxford, UK, 616 pp. http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0470747242,descCd-description.html), and case studies in a Special Issue of the Journal of Geochemical Exploration (Demetriades et al. 2015). In addition, the group has published two urban geochemistry manuals (Demetriades & Birke 2015a, b).

At national and regional levels, the following have been published in Italy: (1) Geochemical Atlas of Italy from GEMAS Database, (2) Different Regional Atlas for Campania Region (the database has been used to publish different papers in peer review journals).

A complete list of publications is available in **EXPLORE 183 Appendix 1** (available for download from the AAG website).

Benedetto De Vivo
Southern Europe Councillor of the AAG

Upcoming Workshops and Short Courses

European Exploration Geochemistry Boot Camp 2019
Email: segfreiberg@gmail.com.

Goldschmidt 2019 Conference Workshops
https://goldschmidt.info/2019/eventTypeView?type=346

SEG 2019 Santiago Chile Workshops
https://goldschmidt.info/2019/eventTypeView?type=346

SGS 2019 Glasgow Short Courses
https://www.sga2019glasgow.com/short-courses

A Better Understanding of Exploration Geochemistry
https://www.csaglobal.com/a-better-understanding-of-exploration-geochemistry/

Introduction to Geological Databases
https://www.csaglobal.com/introduction-to-geological-databases/

2019 Joint Modular Course on the Geochemistry of Hydrothermal Ore Deposits
Email: icsr@uottawa.ca

Geochemistry
EXPLORATION, ENVIRONMENT, ANALYSIS

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CONTENTS - Volume 19, No. 1

The AAG-SGS Student Presentation Prize

The Association of Applied Geochemists, through the support of SGS Mineral Services, awards a prize for the

Best oral presentation by a student at the biannual International Applied Geochemistry Symposium (IAGS)

The intent of this prize is to encourage the presentation of high quality research by students at an International Applied Geochemistry Symposium (IAGS) and provide further incentive to publish the results of the research in the Association's journal, *Geochemistry: Exploration, Environment, Analysis* (GEEA). The winner is determined based on feedback from a group of judges that includes Fellows and Members of the Association. Criteria for judging the presentations include excellence and originality in research design, research execution, interpretation, and the oral presentation itself. Honours, Masters, and Doctoral students are all eligible. The format of the presentation may vary between IAGS.

The Rules

1. The paper must be presented by the student at an IAGS as an oral paper, in the format specified by the IAGS organizing committee.
2. The conference presentation and paper must be largely based on research performed as a student. The student's supervisor or Head of Department may be asked to verify this condition.
3. The decision of the AAG Symposium Co-ordinator (in consultation with a representative from SGS) is final and no correspondence will be entered into.
4. Entry in the competition is automatic for students (but students may elect to "opt out").
5. The detailed criteria and process for assessing the best paper will be determined by the AAG Symposium Co-ordinator in consultation with the AAG Council and the LOC.
6. A paper substantially derived from the material presented at the IAGS and submitted for publication in the Association's journal *Geochemistry: Exploration, Environment, Analysis* within the timeframe specified by the AAG (normally 12 months) will be eligible for the increased value of the prize.

The Prize

1. $700 CAD from SGS Minerals Services (normally presented to the winner at the end of the relevant IAGS) with a further $300 CAD from AAG if a paper related to the oral presentation is submitted to GEEA within the nominated time frame after the IAGS;
2. A 2-year membership of the Association, including subscription to GEEA and EXPLORE; and
3. A certificate of recognition.

David Cohen
Chair of Student Prize Committee
University of New South Wales
Email: d.cohen@unsw.edu.au

CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry. These events also appear on the AAG web page at: www.appliedgeochemists.org.

Please let us know of your events by sending details to:
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Or Tom Meuzelaar, AAG Webmaster,
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2019

23-28 JUNE	Gordon Research Conference: Catchment Science: Interactions of Hydrology, Biology and Geochemistry. Andover NH. Website: tinyurl.com/y9dsvkac
24-27 JUNE	Quantitative Microanalysis 2019. Minneapolis MN USA. Website: tinyurl.com/y8fayprt
24-27 JUNE	13th International Eclogite Conference. Petrozavodsk Russia. Website: igkrc.ru/konferencii-2/922
1-5 JULY	35th International Conference for Society for Environmental Geochemistry and Health. Manchester UK. Website: https://www2.mmu.ac.uk/segh-19/
14-19 JULY	Gordon Research Conference: Discovering Chemical Processes and Mechanisms in a Changing Ocean. Holderness NH USA. Website: tinyurl.com/yahb7f7o
15-18 JULY	6th Annual International Conference on Geology & Earth Science. Athens Greece. Website: www.atiner.gr/geology
21-26 JULY	16th International Symposium on Water-Rock Interaction. Tomsk Russia. Website: wri16.com
22-23 JULY	6th Annual International Conference on Geology & Earth Science. Athens Greece. Website: www.atiner.gr/geology
25-31 JULY	INQUA 2019. Dublin Ireland. Website: www.inqua2019.org
28 JULY – 2 AUGUST	Atmospheric Chemistry (Gordon Research Conference). Newry ME USA. Website: tinyurl.com/yczryngx
4-8 AUGUST	Microscopy & Microanalysis 2019 Meeting. Portland OR. Website: tinyurl.com/y9ejytzy
7-10 AUGUST	11th International Symposium on Environmental Geochemistry. Beijing China. Website: webues.pku.edu.cn/iseg2019
10-16 AUGUST	20th Annual Conference of the International Association for Mathematical Geosciences. State College PA USA. Website: www.iamgconferences.org/iamg2019
12-15 AUGUST	8th International Conference on Medical Geology. Guiyang China. Website: www.medgeo2019.com
18-20 AUGUST	9th International Conference on Environmental Pollution and Remediation. Lisbon Portugal. Website: icepr.org
18-23 AUGUST	Goldschmidt 2019. Barcelona, Spain. Website: goldschmidt.info/2019
27-30 AUGUST	15th Biennial Meeting of the Society for Geology Applied to Mineral Deposits. Glasgow UK. Website: www.sga2019glasgow.com
28 AUGUST - 8 SEPTEMBER	Large Igneous Provinces through Earth History. Tomsk Russia. Website: geoconf.tsu.ru/lip2019/english
1-6 SEPTEMBER	Catchment Science Summer School. Birmingham UK. Website: tinyurl.com/yyjv2ybg
1-6 SEPTEMBER	29th International Meeting on Organic Geochemistry . Gothenburg Sweden. Website: www.imog.eaog.org
2-5 SEPTEMBER	2nd Australasian Exploration Geoscience Conference. Perth WA Australia. Website: 2019.aegc.com.au
8-13 SEPTEMBER	14th International Conference on Mercury as a Global Pollutant. Krakow Poland. Website: www.mercury2019krakow.com/gb
9-13 SEPTEMBER	15th International Symposium on Biomineralization. Munich Germany. Website: www.biomin2019.de
9-13 SEPTEMBER	Multidisciplinary Earth Science Symposium. Prague Czech Republic. Website: tinyurl.com/y5a8gvlm
11-14 SEPTEMBER	9th European Conference on Mineralogy and Spectroscopy Prague Czech Republic. Website: ecms2019.eu
17-18 SEPTEMBER	21st International Conference on Isotope Hydrology and Geochemistry. Rome Italy. Website: tinyurl.com/y8excuwr
22-25 SEPTEMBER	2019 GSA Annual Meeting. Phoenix AZ USA. Website: tinyurl.com/yblcfomo
22-27 SEPTEMBER	International Society for Environmental Biogeochemistry. 24th Symposium. Potsdam Germany. Website: tinyurl.com/y9yngecm

continued on page 19

CALENDAR OF EVENTS...

continued from page 42

23-27 SEPTEMBER	14th International Congress on Applied Mineralogy. Belgorod Russia. Website: www.geo.komisc.ru/icam2019/en
25-28 SEPTEMBER	Mines and Wines Conference 2019. Wagga Wagga NSW Australia. Website: www.minesandwines.com.au
29 SEPTEMBER – 5 OCTOBER	International Conference on Gas Geochemistry 2019. Milazzo Italy. Website: icgg15.pa.ingv.it
7-20 OCTOBER	SEG 2019: South American Metallogeny: Sierra to Craton. Santiago Chile. Website: tinyurl.com/y7k4dm6j
10-13 OCTOBER	2nd Euro-Mediterranean Conference for Environmental Integration. Sousse Tunisia. Website: www.emcei.net
13-18 OCTOBER	9th Hutton Symposium on Granites and Related Rocks. Nanjing China. Website: www.hutton9.com
27-30 OCTOBER	6th International Conference on Selenium in the Environment and Human Health. Yangling/Xi'an China. Website: icsehh2019.csp.escience.cn
29-30 OCTOBER	12th Fennoscandian Exploration and Mining. Levi Finland. Website: fem.lappi.fi/en
6-8 NOVEMBER	XIV Latin American Symposium on Environmental Analytical Chemistry. Bento Gonçalves Brazil. Website: laseac2019.furg.br/inscricoes
25-28 NOVEMBER	2nd Conference of the Arabian Journal of Geoscience. Sousse Tunisia. Website: www.cajg.org
2-6 DECEMBER	American Exploration and Mining Association Annual Meeting. Spokane WA USA. Website: www.miningamerica.org/2019-annual-meeting

2020

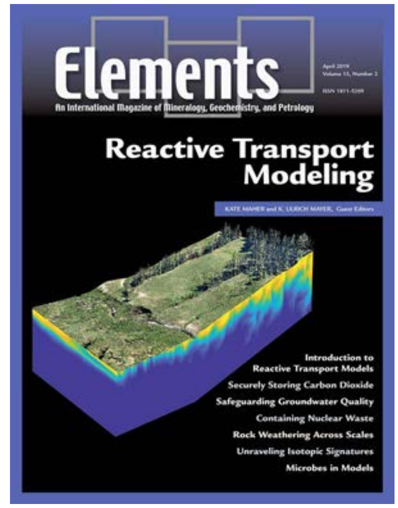
12-18 JANUARY	Winter Conference on Plasma Spectrochemistry. Tucson AZ USA. Website: icpinformation.org
23-27 FEBRUARY	Minerals, Metals & Materials Society 2020 Annual Meeting & Exhibition. San Diego CA USA. Website: www.tms.org/tms2020
1-4 MARCH	Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/convention
2-8 MARCH	36th International Geological Congress. Delhi India. Website: 36igc.org
3-8 MAY	EGU General Assembly. Vienna Austria. Website: www.egu2020.eu
20-24 MAY	Geological Society of Nevada 2020 Symposium Vision for Discovery: Geology and Ore Deposits of the Basin and Range. Sparks NV USA. Website: www.gsnv.org/2020-symposium
24-25 MAY	Geochemistry of Mineral Deposits (Gordon Research Conference). Castelldefels Spain. Website: tinyurl.com/ybkjgl37
14-16 JULY	International Archean Symposium. Perth WA Australia. Website: 6ias.org
17-21 AUGUST	34th International Geographical Congress. Istanbul, Turkey. Website: www.igc2020.org/en
24-28 AUGUST	Eurosoil 2020. Geneva, Switzerland. eurosoil2020.com
18-23 OCTOBER	IWA World Water Congress & Exhibition 2020. Copenhagen Denmark. tinyurl.com/y8tpg3jt
9-13 NOVEMBER	29th International Applied Geochemistry Symposium (IAGS). Viña del Mar Chile.

2021

16-20 AUGUST	12th International Kimberlite Conference. Yellowknife NT Canada. Website: 12ikc.ca

Recently Published in Elements

April 2019, Volume 15, no. 2, Reactive Transport Modeling



This issue of Elements focuses on Reactive transport modeling, or computer simulations of the transfer of mass and energy through the subsurface, which has become a central tool for understanding how Earth's unique chemical environments are formed, how they function today, and how they might behave in the future. AAG news in this issue includes introduction of the new AAG councillors for 2019 and 2020.
Reminder: AAG members can access past issues of Elements at http://elementsmagazine.org/member-login/ using their e-mail address and member ID.

John Carranza