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The Olympic Dam Ore Deposit Discovery — A Personal View

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(see page 19)

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INTRODUCTION

This is a recollection of mentoring and the important events in the pathway to the Olympic Dam ore deposit discovery. The recollection is a personal one, buttressed by discussion with other team players—Dan Evans, Hugh Rutter, James (Jim) Lalor, and Roy Woodall—over the many years since that momentous discovery. Of these, Hugh, the geophysicist at the time of that event, provided the most comprehensive observations and recollections, and his recall of the event is most in accord with my own. His strong scientific curiosity about the large Bouguer gravity and magnetic anomalies in the area in which the deposit occurs (Figs. 1–3) and his technical input were crucial to the success in the memorable last stages of the discovery pathway. Jim's toughness and persistence was also crucial, demonstrated by the long drill program required to find the high-grade and economic part of the orebody, after the initial low-grade copper discovery in drill hole RD (Roxby Downs) 1 in July 1975. The finding of a higher grade section of the orebody took more than a year to realize, following a sequence of eight drill holes, seven of which defined low-grade copper mineralization.

The discovery occurred 30 years ago, with the consequence that memories of it are somewhat blurred. The written record is incomplete and ambiguous, and I have attempted to write the history here as accurately and as dispassionately as possible. It differs significantly from prior published versions, but I believe that such versions lack appropriate description of the roles played by Hugh and Jim in the discovery (Haynes, 1979; Lalor, 1984; O'Driscoll, 1985; Rutter and Esdale, 1985; Esdale et al., 1987; Reeve et al., 1990).

The history spans five years of active metalliferous minerals exploration, and its recollection still generates

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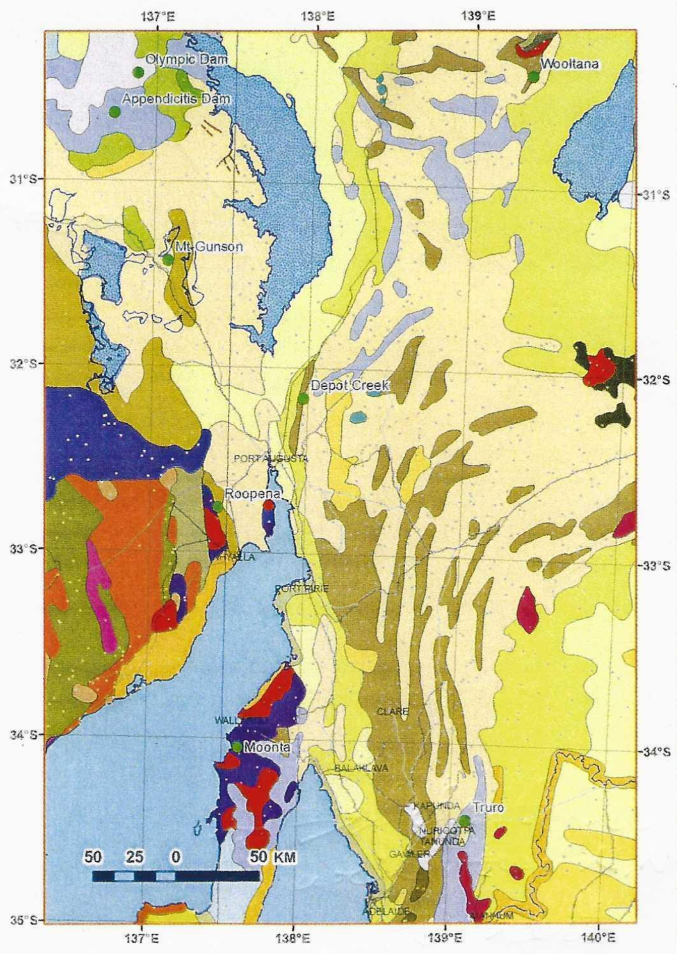

FIGURE 1. The altered mafic volcanic rocks in the Roopena area, shown in the labelled green spot, first drew our attention to the Stuart Shelf, north of here, and ultimately, to the area containing Olympic Dam, labelled in the figure. Here, flat-lying upper Proterozoic rocks, shown in pale brown tones on the map, were thought to conceal extensions of these volcanic rocks, as described in the text. Copper mineralisation within Proterozoic sedimentary rocks at Mt. Gunson also heightened interest in the concealed parts of the Stuart Shelf. Other pale tones are Phanerozoic rocks. Other localities mentioned in the text are the labelled green spots. The geology illustrated here is from the digital version of the A4 Geological Map of South Australia, published by Minerals Energy and Resources, South Australia.

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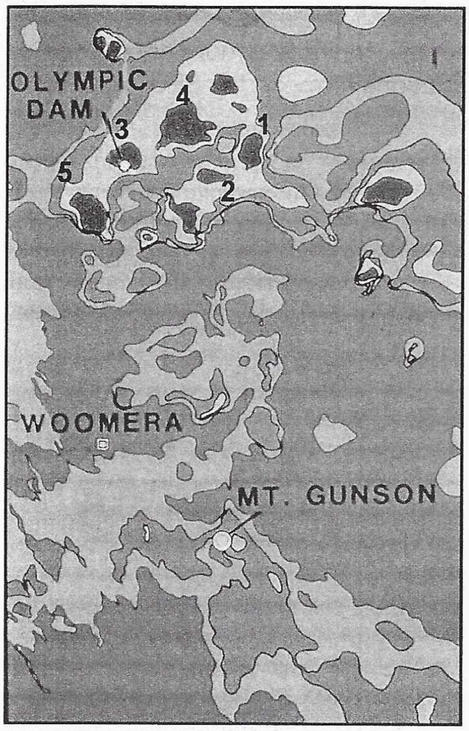

FIGURE 2. Original aeromagnetic data from the Stuart Shelf, with individual contour lines removed, and shaded to highlight anomalies. Numbers refer to anomalies selected by Hugh Rutter and Jim Lalor as being of interest, as described in the text. Note the weaker magnetic anomaly associated with the Mt. Gunson copper occurrence. The diagram is adapted from a set of illustrations prepared by WMC for various public presentations on the Olympic Dam discovery. The aeromagnetic data is from the 1974 public releases of geophysical data from the then Bureau of Mineral Resources, a precursor organisation to Geoscience Australia. The distance between Olympic Dam and Mt. Gunson is approximately 100 km.

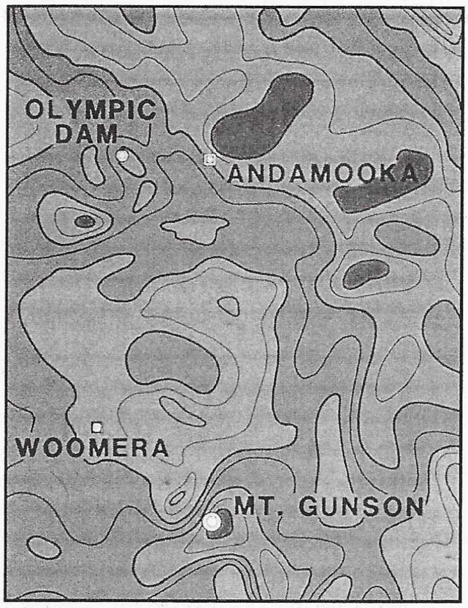

FIGURE 3. Original Bouguer gravity data from the Stuart Shelf, shaded to highlight anomalies. Magnetic anomalies 1 and 2 in Figure 2 are at the NE and SW ends of the large Bouguer gravity anomaly near Andamooka opal field. The Bouguer gravity anomaly associated with the known copper mineralization at Mt. Gunson heightened interest in the anomalies in the Andamooka-Olympic Dam area. The diagram is adapted from a set of illustrations prepared by WMC for various public presentations on the Olympic Dam discovery. The Bouguer gravity data is from the 1974 public releases of geophysical data from the then Bureau of Mineral Resources, a precursor organization to Geoscience Australia.

excitement. It is a history with many implicit lessons, the chief of which is the importance of mentoring, multidisciplinary teamwork, enthusiasm, scientific curiosity, and persistence.

PRELUDE TO THE DISCOVERY: MENTORSHIP

On February 23, 1967, I became a member of the Exploration Division, Western Mining Corporation (WMC), after completing a geology B.Sc. honours degree at the University of Western Australia. WMC was my first choice for employer, despite intense competition from others for the services of geology honors graduates at the University of Western Australia. Even then, WMC had a strong reputation for excellence in the application of geoscience in minerals exploration. Furthermore, WMC was an Australian-owned company, and many undergraduates of the 1960s required Commonwealth scholarships to attend University—so there was an incentive for some of us to at least return the favors bestowed upon us during our undergraduate years. The final "decider" for me was the interview by the WMC chief geologist, J.D. Campbell, then on a recruiting tour through the Australian University geoscience departments. Campbell's discussion of the new and exciting Kambalda nickel discovery, descriptions of WMC exploration division, and his detailed interest in our honors projects catalyzed my decision to join the WMC exploration team.

Thus my experience in exploration for Proterozoic copper deposits began, and with that, the pathway to the Olympic Dam ore deposit discovery through an early posting to the Warburton copper project in central Australia, just west of the eastern border of Western Australia. In this project, the mentoring aspect focused on a very basic four-wheel driving course, on the art of reconnaissance geologic mapping, on handling single-side band radios and radio communication protocols, and on the use of aerial photographs in navigation and their utility as an outcrop locator. Memorable indeed was the aerial photograph training, as my mentor concentrated the training session on particularly featureless country and how to navigate within it using the aerial photographs. My first serious technical contact with Roy Woodall and with other WMC exploration teams occurred at this time—Roy Woodall initiated the Warburton copper project, as he was the first to see the similarity between the small copper deposits in the area and their host basalts and interflow conglomerates here with those of the Keeweenaw Peninsula, Michigan (Cornwall, 1951; Hamilton, 1967; White, 1968; Haynes, 1972). Even then, my contact with Roy Woodall, of necessity brief but episodic, generated a spirit of enthusiasm and excitement in the search for Proterozoic copper.

The sense of enthusiasm and diligence of the exploration teams, most evident in their twice-yearly exploration group technical reviews, coupled with the wonderful sense of dedication, of family, and of pride in belonging to the WMC Exploration Division, was inspiring to a very young geologist. Working with scientists in remote field camps, in new geologic environments, and using the new technologies then deployed in ore deposit search were surely the most profoundly enjoyable experiences I had in those years. There was a strong sense of the importance of care in observation, in its recording, and in the reporting of observations to others in the team and to other teams. Also notable in the mentoring from more senior members of the exploration teams was the critical importance they placed on distinguishing fact from interpretation in geologic mapping. Much of the sense of importance of diligence emanated from Roy Woodall, who took great pride in displaying "factual" geologic maps produced by a particularly diligent team member as examples of how we should record "new" geology in our projects.

From there, my experience in Proterozoic copper exploration led to a search for shale-hosted copper mineralization within the Hamersley basin, northwest Western Australia. Here, the target was stratiform copper within a strongly reduced shale unit, near the base of the Mt. Bruce Supergroup, representing an expansion of opportunities hinted at by several small copper occurrences in the shale found by a local prospector. The work was rather different to that of the Warburton copper project, and much more tedious.

Whereas work in the Warburton copper project comprised geologic mapping utilizing aerial photographs as well as localized, grid-supported mapping of individual copper prospects, copper exploration in the Hamersley basin was a lengthy program of soil sample traversing. This work was within country that severely tested the experience of young geologists in four-wheel-drive vehicles—negotiating the numerous precipitous creeks, retrieving hung vehicles from these creeks, repairing many punctured tires, and relying, during episodic emergency vehicle repairs, more on common sense than on specific expertise. All detailed scale navigating in the difficult terrain used aerial photographs, occasionally augmented by rudimentary topographic maps when the travelling was simpler.

However, near the end of the posting to the Hamersley basin copper project, the team leader provided simple and very well explained lessons in geologic logging of drill core from several short drill holes and, particularly, in transferring his considerable experience on factual geologic mapping, especially concerning the skills required to produce accurate outcrop maps within surveyed grids.

PRELUDE TO OLYMPIC DAM

After the Hamersley basin project, which lasted six months, a detailed and very extensive drill-core logging project on Proterozoic copper-gold-magnetite mineralization in the Moonta area of South Australia commenced in February 1968 (see Fig. 1 for location). The project was my first work on a type of mineralization now known as the iron oxide copper-gold style, which indeed occurs in the same geologic province that hosts the Olympic Dam deposit (e.g., Parker, 1990; Skirrow et al., 2002, 2006). The path to the Olympic Dam ore deposit discovery had taken an interesting turn with the Moonta project work.

Moonta presented a dramatic contrast to that of the previous 12 months of minerals exploration within WMC, in that it required the relogging of drill core in an attempt to correlate mineralization between drill holes in the intensively drilled West Doora prospect near Moonta. The task was not an easy one for an inexperienced geologist, as the complex geology and alteration, unrecognized at the time, defeated all prior attempts at correlation. It was also my introduction to an extensive and very detailed drill core logging program; unfortunately, and indeed, for the only time in my WMC career, the essential mentoring was absent, with much of my drill-core logging consequently of a poor and inconsistent nature. Nevertheless, an illustrated summary report containing long and cross sections, with illustrations of correlations between mineralized drill intersections and auger drill-defined geochemistry in the near surface, was completed for the project in December 1968. One of the conclusions was that mineralization found was not strata bound but a complex, veinlike array of "pegmatite-style" mineralization that made the desired correlation difficult. In any case, the significance of complex albite-actinolite-scapolite ("sodic-calcic") alteration associated with the West Doora iron oxide copper-gold mineralization went unappreciated upon completion of the project (e.g., Hitzman et al., 1992; Skirrow et al., 2002).

As subsequently discovered, many years later, this record, written up as an illustrated draft, was lost in an office reorganization before it was formalized as a WMC exploration report. Timely recognition of the loss did not occur because I had taken leave of absence to commence work toward a doctorate degree at the Australian National University. And it was here that the first critical input of Roy Woodall into the discovery of the Olympic Dam ore deposit was made.

On joining WMC, I had formulated a strategy to work in exploration for two years and then return to a university to do research. I decided, during the work at Moonta-Wallaroo, that research on Proterozoic copper was rather an appropriate topic because of my continuous exposure to exploration within the Australian Proterozoic, and because copper was a commodity of great interest to WMC.

Here, Roy Woodall, in discussions on the possible study leave topic in mid-1968, noted that WMC was selling nickel to customers who expressed an interest in copper, and that research on Proterozoic copper was indeed very desirable. Based on my inclination and this advice, Proterozoic copper became the broadly defined focus of my study leave project.

Roy Woodall's critically important contribution continued, as he most strongly emphasized the requirement that the postgraduate study be performed at a university of international reputation, where exposure to good science and groundbreaking ideas was maximized. So, after more discussion, the choice became the Australian National University (ANU). A mineralogical and geochemical study of the altered basalts of the Warburton area, the alteration, and its relation to chalcocite-hematite veins within the basalts ultimately became the topic for my postgraduate research at the ANU. At Roy Woodall's behest, WMC provided all support for fieldwork in the Warburton project area.

The work at ANU provided me with an opportunity to meet Allan White, and his mentoring dramatically improved the quality of my research. Others at ANU in the late 1960s included Bruce Chappell, Wayne Burnham, and David Green.

By early 1972, the research showed quite convincingly that continental tholeiite basalts, when altered to albite-hematite-phyllosilicate-epidote-carbonate assemblages, become potent sources of copper, with their capacity to act as copper source rock dependent on their Fe^{3+}/Fe^{2+} ratios, and total Na (as albite) contents (Haynes, 1972). These results demonstrated that the research was of likely critical importance in the future exploration for Proterozoic copper deposits. The potential value of this research in future minerals exploration resulted in part from Roy Woodall's foresight in suggesting the topic of the research.

Armed with a "new" exploration model

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generated by the research, I recommenced work in exploration for Proterozoic copper within Australia in August 1972, immediately on return from the ANU to the WMC Exploration Division Kalgoorlie office. Roy Woodall, now the chief geologist, provided an environment of near-complete freedom in which to operate on my return. This freedom, I believe, ultimately led to the success in Olympic Dam ore deposit discovery, and indeed, to several subsequent discoveries.

FOCUSING ON A MODEL

A key tactic at the beginning of the new role was to focus on definition of all occurrences of basalt, particularly continental tholeiite, within the Australian Proterozoic. Once such definition was complete, the focus would be refined through selection of occurrences altered to hematite and associated minerals such as epidote and albite. Deployment of interesting sources of information characterized such work; for example, compilations of Australian basalt analyses in Joplin (1963) were searched for analyses showing high Fe^{3+}/Fe^{2+} ratios, high Na, and LOI values.

The focus on definition of altered basalts source rocks of the copper deposits was very deliberate—firstly, because the research demonstrated that they were potent copper sources, and secondly, because current mapping and geologic documentation would be less likely to obscure such rocks because of their ease of recognition and their large volumes. By contrast, host rocks, represented by volumetrically insignificant "reduced" (i.e., pyrite- or pyrrhotite-bearing) sedimentary rocks, which are usually recessively weathered in the Australian Proterozoic, could readily be hidden and were not yet identified in published geologic maps. The current generation of published Australian geologic maps in 1972, although locally of good quality, was of insufficient detail in scale to promote a successful copper search based upon definition of potential host rocks alone.

After several months' work in definition of likely copper source rocks, however, a requirement for geographic focus arose because of the large spread of apparently altered basalts in the Australian Proterozoic. In late 1972 or early 1973, Roy suggested we start with South Australia.

Broad-area, geologic ingredient maps illustrating all occurrences of Proterozoic basalt and amphibolite encapsulated the early target definition work on South Australia, with these maps displaying extremely simplified representations of areas where Proterozoic sedimentary successions (or their metamorphosed derivatives) occurred above concealed basalts or amphibolites. The model which drove the early work focused on a location for the target within reduced sediments adjacent to major faults that "tapped" hydrothermal fluids emanating from the underlying oxidized and altered basalts, with the basalts occurring 1 km or so below the inferred copper host unit. By May 1974, this work highlighted areas in the northern end of the Flinders Range near Wooltana, in the central part of the Flinders Range at Depot Creek, in the southern part of the Flinders Ranges northeast of Adelaide at Truro, and southwest of Port Augusta in the Roopena area, as well as a number of other areas containing amphibolite on the Eyre Peninsula (for locations of these areas, see Fig. 1). The early emergence of areas of interest within the Proterozoic of South Australia, coupled with the well-known copper endowment in better-exposed Proterozoic rocks here, provided additional impetus for continuation of the copper exploration program in South Australia.

Jim Lalor, the team leader and manager of exploration in the eastern part of Australia, Hugh Rutter, the geophysicist for the eastern Australian exploration group, and Dan Evans, the South Australian exploration team leader, became very strong supporters of the project as soon as its modus operandi and aims were described to them. Hugh's interest in the project commenced with a broad-area geophysical interpretation of the key Proterozoic geologic domains of South Australia. In this study, emphasis on definition of major faults and major gravity anomalies highlighted the western margin of the Gawler craton. Although the work did not specifically highlight the area of the Olympic Dam deposit, it proved the precursor of the later and crucial geophysical interpretation that defined the Olympic Dam geophysical anomaly as one of five anomalies of interest on the "Stuart Stable Shelf," as the northeast part of the Gawler craton was then known (Thomson, 1975).

With exploration infrastructure and the office in place in Flagstaff Hill, an outer suburb of Adelaide, the project moved to South Australia. Dan's input at this stage of the project was morale-boosting, with great support given through his sheer enthusiasm coupled with unstinting assistance in the use of exploration base facilities during the various field reconnaissance spells, and through numerous discussions presenting alternative points of view, which improved operational procedures. Even at this relatively early stage of the program, Jim and Dan's support was especially important in dispelling some of my strong uncertainty and doubts attending application of an untried copper deposit-targeting model, especially because emphasis was to be on exploration for blind or concealed copper mineralization.

Concurrent with the move to South Australia, field inspections of altered basalts at Depot Creek, Truro, and Roopena, by the team made up of Jim, Dan, Hugh, and me, confirmed that the basalts at Roopena displayed appropriate alteration (Fig. 1). Later, analytical data on samples of the Roopena Volcanics showed pronounced copper depletion; data from the other areas either generated equivocal interpretations or were negative (see Knutson et al., 1992, for description of the copper depletion within the Roopena Volcanics on the Stuart Shelf). The copper depletion signature of the Roopena Volcanics drew immediate attention to the adjacent parts of the Stuart Stable Shelf next to but west of the Torrens hinge zone, especially where covered by flat-lying upper Proterozoic sediments (Fig. 1). The Torrens hinge zone was an interpreted set of major faults defining the east margin of the Stuart Stable Shelf (Thomson, 1975). Could this area contain copper deposits within reduced sediments next to the major fault zones tapping altered basalts here, where they were hidden by the flat-lying upper-Proterozoic sediments?

The next crucial question requiring resolution was where in the Stuart Stable Shelf west of the Torrens hinge zone should exploration for the hidden copper deposits commence? Rather dramatically, one of two answers presented itself. The Bureau of Mineral Resources, a precursor organization to Geoscience Australia, released broad-area preliminary line compilations of the aeromagnetic and gravity potential field data collected in recent surveys in this region. There were several extensive and high-amplitude Bouguer gravity and magnetic anomalies clustered in a region west of the northern sector of the Torrens hinge zone, in the area now known to contain the Olympic Dam deposit (Figs. 1–3). These data, provided by WMC geologic support staff in the Kalgoorlie office following a request for such data, were then sent to Hugh in the WMC Preston (Melbourne) office, accompanied by a note highlighting the potential importance of the gravity and magnetic anomalies. Could these represent hidden, fault-bound basement uplifts containing thick sequences of altered basalts? Could the margins of these gravity highs be of interest for sediment-hosted copper mineralization within reduced sediments next to faults defining the margins of the inferred basement uplifts?

It was also thought at the time the other answer could be provided by lineament-tectonic analysis. I believed that locations of major but hidden faults, thought to be important in the genesis of the copper deposits, could perhaps be definable through lineament tectonics. Accordingly, in late 1973, a request for a lineament tectonic analysis of the northeast Gawler craton was made to the lineament tectonics group, headed by Tim O'Driscoll. However, strong attention by the lineament tectonics group to analysis of the areas around nickel deposits in the Yilgarn craton precluded immediate commencement of the work. Analysis of the northeast Gawler craton finally commenced in March 1974 and progressed as Hugh began his crucially important analysis of more detailed (still very basic by today's standards) line compilations of the Bouguer gravity and magnetic potential field on the Stuart Stable Shelf.

In June 1974, Hugh estimated possible sizes, configurations, and depths of the sources of the major Bouguer gravity and magnetic anomalies here, with this work defining five geophysical anomalies of interest (Fig. 2). The anomalies that Hugh selected were under the west margin of Lake Torrens (1 in Fig. 2), an anomaly ("2") under the Andamooka opal field, in the opal field ("4"), the anomaly at Olympic Dam ("3"), of particular interest as it had the shallowest interpreted depth to source, and a fifth anomaly, at Appendicitis Dam (now Acropolis), ~30 km south of Olympic Dam ("5"). A heightened interest in these anomalies stemmed from the observation that copper mineralization within Proterozoic sedimentary rocks ~100 km south of here displayed a close association with lower amplitude and less extensive magnetic and gravimetric anomalies (Fig. 2). In an internal memorandum on the interpretation and anomaly selection, Hugh noted the difficulty of "fitting" the interpretation to the "altered basalt model," but he specifically noted that these anomalies were of great interest, with the anomaly at Olympic Dam possibly representing a fossil volcanic center! This was a most extraordinarily prescient and felicitous interpretation indeed, particularly in view of the absence of hard evidence for such an interpretation. In my discussions with Hugh shortly after completion of the interpretation, he expressed tremendous enthusiasm and scientific curiosity. He noted that all five anomalies were "very interesting" because of their configuration, high amplitudes, and extensiveness, and they consequently deserved testing in their own right, i.e., irrespective of the nature of the geologic model used to highlight interest in them.

I recollect this conversation very clearly, particularly because of Hugh's enthusiasm and the memory of the small back office with the maps showing the raw line compilations of the potential field data coupled with simple sketches of the geophysical interpretations, which Hugh described to me during the visit. Dan also noted in an internal memorandum at about this time that several anomalies required testing in order to "optimise the probability of hitting the elephant by chance," because of the relatively large area in which the anomalies occurred. So the work of Dan, Hugh, and Jim progressively built up the sense of momentum and accompanying excitement as the project moved closer to the drill-testing stage. By this time, the encouraging results of the geophysical interpretation, Jim's leadership, and the strong support of Dan and Hugh had dispelled my doubts and concerns relating to the basalt-alteration model driving the exploration process.

The lineament tectonic analysis defined 21 tectonic targets over a large region of the northeast Gawler craton, with several of these on or near the geophysical anomalies selected as being of interest by Hugh; this association also heightened interest in the anomalies. After the tectonic analysis work was completed, Hugh and Jim, working together, utilized the geophysical interpretations, the geophysical anomaly maps,

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topographic maps, and the tectonic target maps to define exploration targets centered on the coincident magnetic and gravimetric anomalies in the northeast sector of the Stuart Shelf. The anomaly at Olympic Dam and another farther south, at Appendicitis Dam (now the Acropolis Prospect), were selected for an initial test because, firstly, they were the only two readily accessible anomalies, and secondly, because the anomaly at Olympic Dam had the shallowest interpreted depth to source. The lack of access tracks and roads coupled with limited exploration funds precluded testing of the geophysical anomaly under Lake Torrens and the anomaly northwest of the Andamooka Opal Field. An inability to obtain mineral exploration licence coverage of the anomaly under the opal field likewise precluded access to the geophysical anomaly there. However, none of the tectonic targets in or near the five geophysical anomalies of interest were programmed for a test, and nor did they influence the selection of geophysical anomalies programmed for testing.

DISCOVERY

In the last exploration review prior to the drill program in the WMC Preston office in late 1974, Dan, Hugh, and Jim drove the dynamics of the review and formulated a test program for the two geophysical anomalies of interest. All played a vital, indeed crucial, role in ensuring that the proposed two-hole drill program, focused on the anomalies at Olympic Dam and at Appendicitis Dam, proceeded. As emphasized in my descriptions of the exploration model at the review, such testing required drilling into the inferred altered basalts beneath the potentially prospective Proterozoic sedimentary sequence, with at least a 150-m drill interval required in order to obtain an adequate sample in order to observe the alteration and to test them for copper depletion. There was much argument as to the magnitude of the drill interval required, but following vigorous discussion, a compromise 50-m interval was selected. If such a compromise had not occurred, the Olympic Dam ore deposit may well have remained undiscovered—if that first drill hole was terminated at the unconformity.

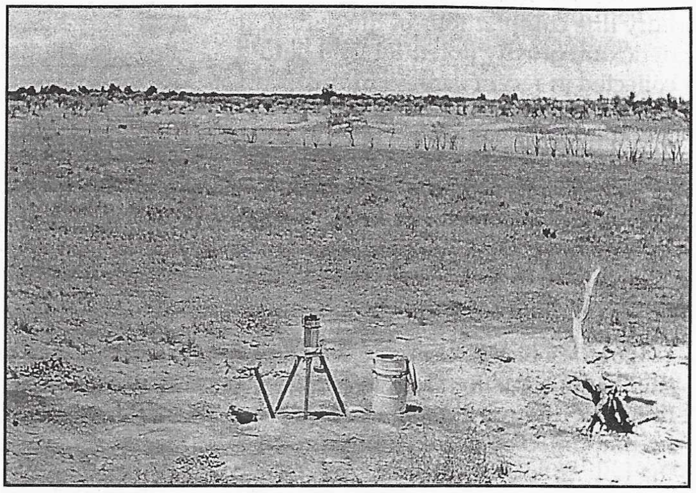

FIGURE 4. A gravity station and gravity meter at the site of the first proposed drill hole, Roxby Downs Number 1 (RD 1), in early 1975. The Olympic "dam," an excavation containing water for cattle, is visible in the background. View is looking approximately NE. Hugh Rutter provided all photographs featured here.

The remainder of the discovery history of the Olympic Dam deposit is reasonably well documented, although two more points require noting, so that the important roles played by Jim and Hugh in this discovery are clear. Firstly, Hugh, after an arduous and long drive to the exploration locale in a hired car, marked the position of the first proposed stratigraphic drill hole at Olympic Dam (Figs. 4, 5). The hole, sited sufficiently far from the dam so as not to disturb stock, but close enough to facilitate a water supply for the drilling crew, was to test the steepest part of the gradient on the southwest margin of the Bouguer gravity anomaly, now more closely defined through ground-based follow-up geophysical programs. Secondly, Jim had the foresight and toughness to persist with a nine-hole drill program at Olympic Dam despite slackening interest in the project caused by a sequence of drill holes displaying low-grade copper mineralization. In this resolve, Hugh provided able support, noting that interesting parts of the geophysical anomaly, of vast extent, required further drill testing.

Two anecdotes on the discovery also deserve mentioning here. The first occurred when drill core from drill hole RD1, the initial test hole at Olympic Dam, was laid out for inspection outside the WMC Exploration Division field office at Flagstaff Hill. On a very cold and rainy day in late July 1975, Dan and I inspected the drill core and could not determine the nature of the rocks within it. They were certainly not altered mafic volcanic rocks, although they appeared to be intensely altered and hematite rich. Even inspection with hand lenses did not alleviate our puzzlement. With the continuing cold and rain, we both retired to the warmth of the office for coffee to consider the implications of the unusual rocks in drill hole RD1.

Just then, the preliminary analytical results from chip sampling of the drill core arrived by post from the WMC analytical laboratory. Dan, on inspecting the results, which were handwritten in columns on a standard WMC analytical results form, said, "Look at this, look at this!" And his excitement was palpable, as a long string of assays revealed between 0.5 and 1.5% copper contents in the chip samples, with an average close to 1% over a drill interval

FIGURE 5. Bernie Milton, leader of the South Australian Mines Department seismic crew loads shot holes for the seismic traverses completed during the program aimed at definition of basement structure in the area of the Olympic Dam and Appendicitis Dam geophysical anomalies in early 1975.

of 40 m, with copper values of the order of 1% at the end of the hole! With great enthusiasm, we both returned to the cold and rain and inspected the drill core again, looking for copper sulfides, which were very difficult to observe. We did not see the chalcocite, but we did see traces of bornite and chalcopyrite. The fine-grained nature of the chalcocite and its occurrence within fine-grained hematite precluded its ready identification, even with a hand lens. With the thrill of this discovery, we returned to the office, where Dan estimated a resource of 80 million tonnes of mineralization at 1% copper, with calculations based on a block of mineralization 1 km^2, centered on drill hole RD1, using the vast size of the gravimetric anomaly here as a very conservative constraint in the selection of the 1-km limit!

The next anecdote pertained to drill hole RD 10 at Olympic Dam, completed in November 1976, and it directly reflects Jim's wonderful leadership qualities. After more than a year of drill-testing the Olympic Dam gravimetric anomaly, the failure of a program of eight drill holes to define higher grade copper mineralization (most contained 1% copper over drill intervals ranging from 10 to 90 m thick), was blunting my interest in the project. Morale was also low because of an announcement by a competitor of an apparently significant stratiform copper discovery near Port Augusta. The implication of such an announcement was that the exploration model we used in the South Australian Proterozoic copper program had missed significant copper mineralization during the earliest stages of its application. Consequently, I had to visit the local exploration office in an attempt to retrieve the situation.

Jim and David O'Connor, Dan's successor as the officer-in-charge of the South Australian exploration team, surprisingly and most unexpectedly met me upon arrival at Adelaide airport, and noted we could perhaps look at drill core from the latest Olympic Dam drill hole, RD 10, on the way to the office. At the drill core yard, Jim indicated the location of core from drill hole RD 10 and said that I, perhaps, could go and look at it, as he and David had to attend to "other business." My subsequent solo inspection of the drill core from RD 10 generated a quite staggering surprise and great excitement: it revealed a 200-m-thick interval of mineralization containing spectacular, large masses of chalcocite, bornite, and chalcopyrite, with my early visual estimates of grade ranging from 2 to 4% copper over drill core intersection widths ranging from 100 m to 200 m! After I had realized that here was a truly gigantic ore deposit discovery, Jim reappeared and asked, "Well, what do you think?" He and David had made sure that my inspection of drill hole RD 10 would be a complete surprise. This surprise is still the most enjoyable recollection of a long minerals exploration career.

The discovery of the Olympic Dam deposit is a good example of strongly collaborative, multidisciplinary teamwork, in which geochemically oriented geology and geophysics played the defining roles. Roy Woodall, and then Prof. Allan White, set the initial mentoring framework for the discovery, and Roy Woodall, through crucial early advice and recommendations, steered the Proterozoic copper exploration program to South Australia. After generating interest in the geologic province containing the Olympic Dam deposit, enthusiastic support for the project by Jim, Hugh, and Dan proved vital in the pathway to the discovery. Then the project became geophysically oriented and consequently very much driven by Hugh's expert input. Jim provided the leadership, requisite toughness, and persistence to continue the test program such that discovery of the gigantic orebody followed.

Thus, several geoscientists together with their diligent and hard-working support staff were principally responsible for the Olympic Dam discovery. Of this group, Jim was the prime mover, providing the fun, leadership, and experience that guided the young team working in the exploration program, although mentoring continued at many levels in this discovery, and provided an essential ingredient in the discovery. All of the players, too, operated within the WMC Exploration Division framework of scientific diligence in observation, in recording and in reporting, within an environment that promoted active and vigorous discussion of scientific questions as

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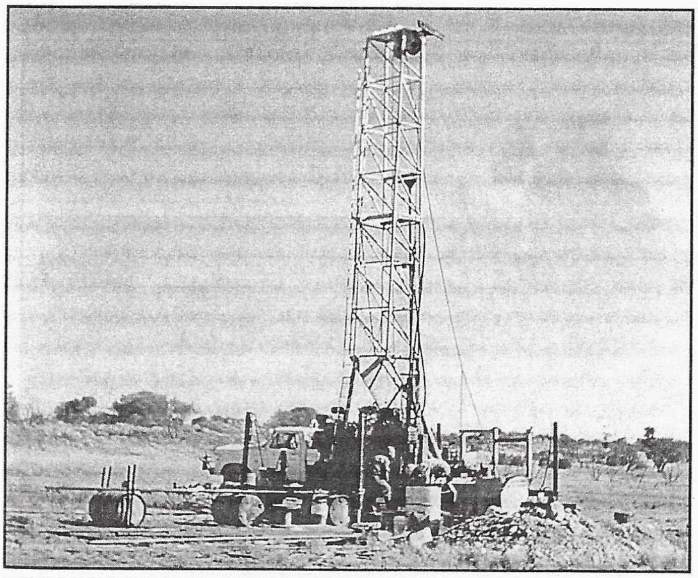
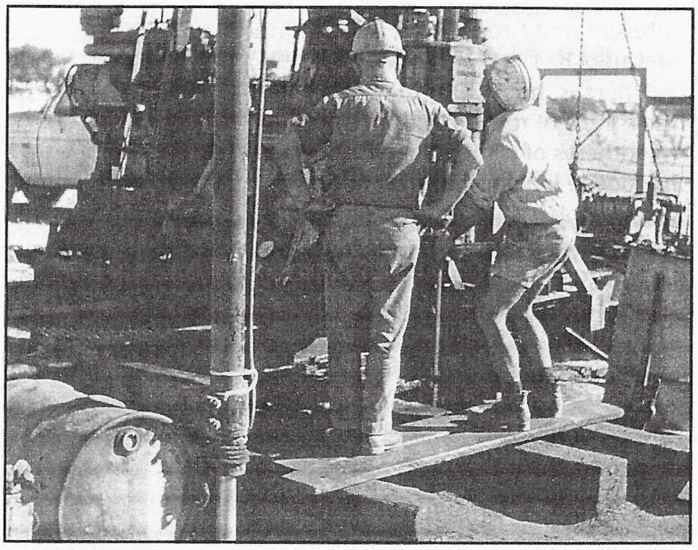
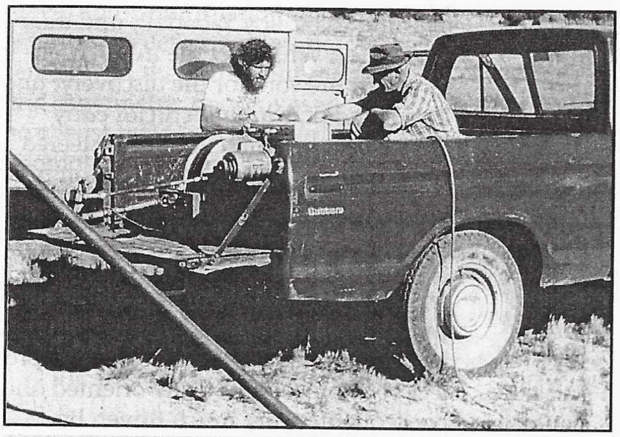


A drill rig on drill hole RD 1, in mid-1975. View is looking approximately north. Ted Whenan is the driller.



Ted Whenan (closest to camera) and his drill offsider during the drilling of RD 1. The first mine shaft at Olympic Dam was named after Ted Whenan.

··· from 13 The Olympic Dam Ore Deposit Discovery — A Personal View (Continued)



Rowan Evans and Terry Brooks (in the truck) performing geophysical logging of drill hole RD 1 in mid-1975.

they related to minerals exploration. Roy Woodall justifiably deserves the greatest credit for indirectly contributing to the discovery though the development and management of this framework and operating environment.

The Olympic Dam ore deposit discovery was partly serendipitous, but only partly so, because geophysics drove the dynamics of the exploration history in the vital end stages of the discovery pathway. Certainly, the deposit is not of the style sought by the altered basalts model. However, altered mafic volcanic or intrusive mafic rocks comagmatic with the Roopena Volcanics most likely sourced much of the copper and gold within the deposit and in situ sulfate-reduction coupled with ferrous iron oxidation likely generated the orebody (see, for example, Knutson et al. 1992; Johnson and Cross, 1995; Johnson and McCulloch, 1995; Haynes et al., 1995).

There is, however, much debate on the source of metals in this deposit, with hypotheses of a subvolcanic "hot-rocks" hypogene leaching source, or a porphyry copper-style magmatic source, or a predominant alkaline felsic or alkaline ultramafic magmatic source prominent in the published research (e.g., Oreskes and Einaudi, 1990; Haynes et al., 1995; Johnson and McCulloch, 1995; Campbell et al., 1998). These competing hypotheses require additional research to resolve this important question because they differ so dramatically in their postulates on metal sources. Ideally, a focus of such research on elucidation of multiple metal sources would speed resolution of this key problem and the complex geochemistry and mineralogy of the deposit indicates it is most unlikely that a single rock type sourced all of the economic metals in the Olympic Dam deposit (Reeve et al., 1990).

I was 30 years old during the discovery of the Olympic Dam ore deposit. Even then, at that relatively early age, and despite the euphoria coupled with the numerous thrilling discussions on the nature of the ore deposit with colleagues, I recognized that I would be very fortunate indeed to be involved in another success of such magnitude. Although several more significant ore finds followed, all were smaller, and none precipitated the excitement and extraordinary enthusiasm of the Olympic Dam ore deposit discovery. But all successes were generated through my very good fortune to be part of a first-rate minerals exploration organization comprised of first-rate scientists, charismatic leaders such as Jim Lalor, and within an environment, created by Roy Woodall, that emphasized excellence and camaraderie. The composition of the organization and its modus operandi were far ahead of its time, and through the foresight of Roy Woodall, it became one of the most successful minerals exploration organizations in the 1970s and 1980s.

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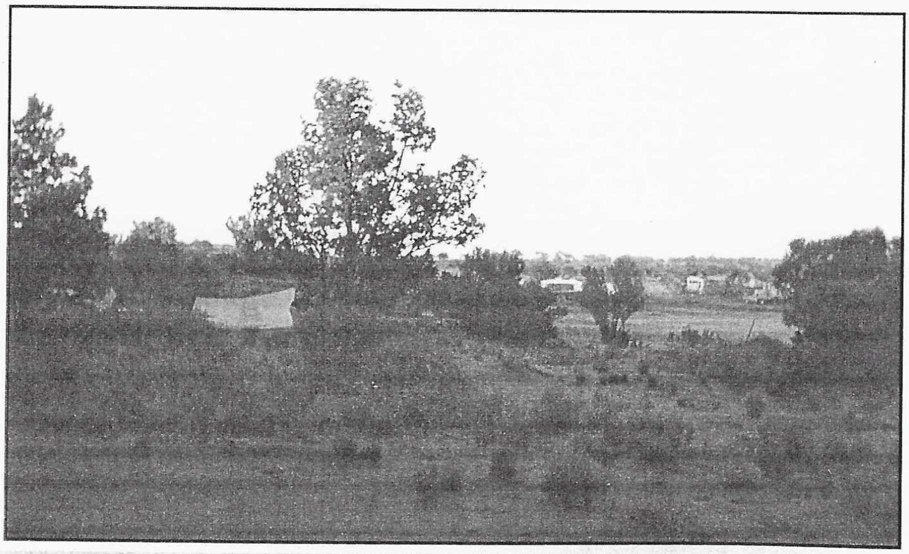

On-site camps during the drilling of RD 1. In the foreground is the geophysical logging crew's tent; in the background are the drillers' caravans and vehicles.

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