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River Bank Collapse on the Nepean River in the Wallacia Valley: Assessing Possible Causes by Historical and Geomechanical Methods

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Abstract: River banks of the Nepean River within the Wallacia Valley are subject to widespread upper bank collapse and erosion of the lower bank toe. An historical approach by aerial photograph analysis, and a geotechnical approach by slope stability modelling has been used to determine the influence of human-derived modifications on this morphological change. Widespread collapse of the Nepean's banks occurred primarily during a relatively wetter climatic period between 1949 and 1970 and was most noticeable on banks cleared of vegetation. Stability analyses conducted on representative bank profiles indicate the strong cause and effect relationship between devegetation and mass-failure of riverbanks. A riverbank of average morphological dimensions experiencing rapid drawdown presents as stable in the vegetated case and unstable in the devegetated case. Wind-wave erosion on the weir-lake has probably eroded bank toes by up to two metres. Changes in bank angles resulting from in-channel sand and gravel extraction also reduce bank stability although such activities largely post-date the main period of bank collapse and consequently they are not considered to be a major cause of failure. Human influence via devegetation and weir construction has been paramount in causing significant morphological change to this particular riverine environment.

Keywords: River-bank failure, Nepean River, Slope-Stability Modelling, Anthropogenic Change, Devegetation

INTRODUCTION

Recent morphological change on the Nepean River has been well documented and examined (Warner 1987a & 1994, Hubble & Harris 1993, Hubble 1996, Erskine & Green 2000). These works describe a period of severe degradation through channel widening with the processes involved including both large-scale mass collapse and fluvial entrainment. A variety of human-induced and natural causes have been implicated in these processes and they consist of: climatic shift, devegetation, dam and weir construction, channel dredging, and channel incision due to planform stability. The extent to which these factors operate within the Wallacia Valley has been largely unstudied as detailed morphological observations of this section of river are limited.

The examination of changes in riverine morphology requires at least two sets of data. One prior to any change and one post-change. If two widely separated sets of data are available perceived change will be indicative of the total alteration and will not allow discrimination of the contributions of several potential causes. Multiple sets of closely spaced observations reduce the time periods between surveys and thus allow greater certainty in determining the relationship between morphological change and its occurrence in time. Consequently, associations between individual causes and their resulting effects are made clear.

In examining the timing of large-scale mass collapse along the Nepean River the aerial photographic record is particularly useful due to the relative frequency of repeat survey images. Although not as beneficial as frequent cross-section and long-profile surveys for examination of changes in width/depth and subsequent channel capacity, aerial photographs provide a comprehensive catalogue of the timing and location of large circular failure scarps throughout the study area. The widespread occurrence of such failures indicates a stream in a state of change by widening.

Riverbanks are in effect a type of soil slope and as such can be examined using conventional soil slope stability models. In simple slope stability analysis the factors responsible for influencing the outcome involve adjustments to the media of the slope by two mechanisms: (1) an altering of the internal strength; and (2) an altering of the bank morphology (see Lambe & Whitman 1979). Therefore changes to the stability of riverbanks should come about due to change to one or both of these mechanisms.

An altering of the internal strength of the riverbank implies a change in value of one or more of the parameters given in Coulomb's soil shear strength equation:

$$\tau = c + \sigma_n tan\phi$$

where (τ= shear strength of the soil; c = cohesion of the soil; (σ_nn = the total normal stress on the shear plane; and ϕ = the angle of internal shearing resistance of the soil. In a riverine environment changes can occur to all three parameters: (a) Normal effective stress changes due to flood saturation of banks and natural and surcharge weight of riparian vegetation, (b) Soil cohesion changes due to variations in the density of riparian vegetation (Hubble & Hull 1996) or variations in soil type between sites, and (c) Internal friction angle changes due to variations in soil type between sites.

On the other hand altering the morphology of a riverbank, particularly changing its angle of slope, greatly affects the stability of that bank (Simon 1989, Hubble & Hull 1996). An increase in slope results in a greater down-slope force relative to its normal restoring force therefore increasing the likelihood of bank collapse (see Fig. 1).

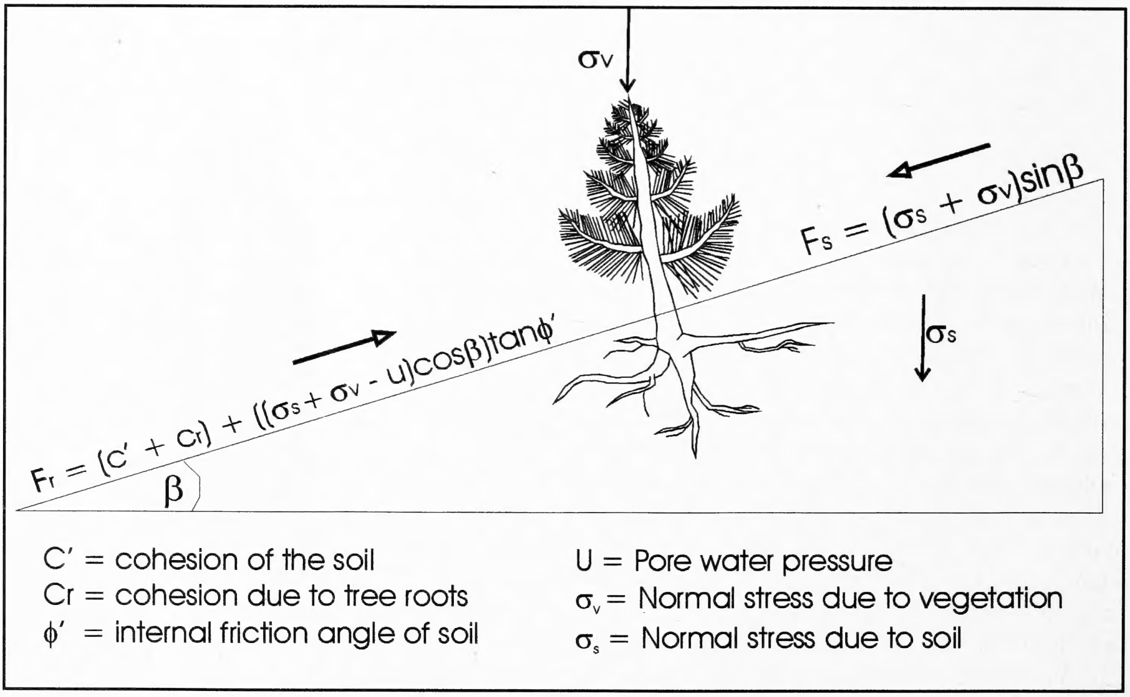

Figure 1: The forces in place on a vegetated slope. Forces acting down the slope are due to the weight of the soil and vegetation in the parallel direction to the slope. Restoring forces acting up the slope are due to the internal strength of the soil and the weight of the soil and vegetation in the normal direction to the slope.

By examining individual banks it is possible via slope stability analysis to determine the conditions required to cause mass collapse. Studies presenting such a geomechanical approach to explain riverine processes are rarely attempted. Hubble & Hull (1996) Hubble (1998) and Abernethy & Rutherfurd (1998, 2000) are exceptions.

An understanding of the processes by which morphological change occurs within a river and on its floodplain is essential for effective riverine management. Determining the influence of probable factors in causing such change is therefore a critical step in the remediation of excessive erosional product. This paper reports on a study that has done just that for a small reach of the Nepean River west of Sydney. It provides historical and geomechanical evidence that a combination of human and natural phenomena are responsible for the substantial increase in erosional process in the second half of the 20th century.

LOCATION AND GEOLOGICAL SETTING OF STUDY AREA

The study area encompasses the river channel, banks and nearby floodplain of the Nepean River between Bents Basin and Wallacia Weir (Fig. 2). It covers approximately 10 km of river channel comprising a thin Late Pleistocene to Holocene fluvial sequence deposited within a relatively narrow and ancient bedrock valley. The valley is cut into Wianamatta Group Shales and Hawkesbury Sandstone. The morphology of the channel in the Wallacia Valley is quite distinct from the steep gorge reaches immediately upstream and downstream, and as a result responds differently to changes in water and sediment discharge. Both types of channel are limited in the extent to which they can change due to the restriction on channel migration imposed by the shale and sandstone basement. Climatic, eustatic, and tectonic events have caused this stream to be deeply incised (Hicken 1967). In addition to these longer term events recent down-cutting appears to have lowered the existing channel in relation to the alluvial flats (Hicken 1967). This control limits change in parameters such as meander wavelength, gradient, and sinuosity (Warner 1983). As it exists today the planform geometry of the Nepean River near Wallacia is that of a low-sinuosity stream constrained in its current location by a bedrock valley that by all accounts is in a state of long-term stability (Bishop 1982, Bishop, 1986, Hubble & Harris 1993). Episodic periods of gradual vertical accretion and catastrophic stripping dominate the morphological development of such laterally confined bedrock valleys in Eastern Australia (Nanson & Erskine 1988, Nanson 1986).

The stability and bedrock incision of the Nepean River has resulted in a relatively deep channel with banks that may be "over-steepened". At the same time vegetation has armoured and strengthened the banks to enable the existence of slopes at or above the soil's limit of stability (Hubble, 1997). This situation would not have resulted if alluvial materials were deposited by a freely meandering stream and it has particular significance when investigating bank erosion because over-steepened banks tend to be prone to mass collapse.

The riverbed within the study area consists of some fine gravel, and sands that are classified according to criteria in Stace et al. (1968) as Siliceous Sands. These sediments are more erodible in comparison to the stable, finer grained, cohesive banks that consist of deep, friable, weakly structured brown loams and sandy loams (Walker 1960), classified as Alluvial Soils or Minimal Prairie Soils (Stace et al. 1968).

HYDROLOGICAL REGIME

Since the late 1940s there has been a dramatic shift to a wetter climate in southeastern New South Wales (Pittock 1975, Cornish 1977). Kraus (1955) also recognised that annual rainfall in New South Wales was much greater in the latter part of the 19th century than in the first half of the 20th century; prompting some workers to investigate the existence of alternating climatic regimes (Erskine & Bell 1982, Warner 1987a, Erskine & Warner 1988) characterised by periods of wet and dry years on a 30-50 year cycle.

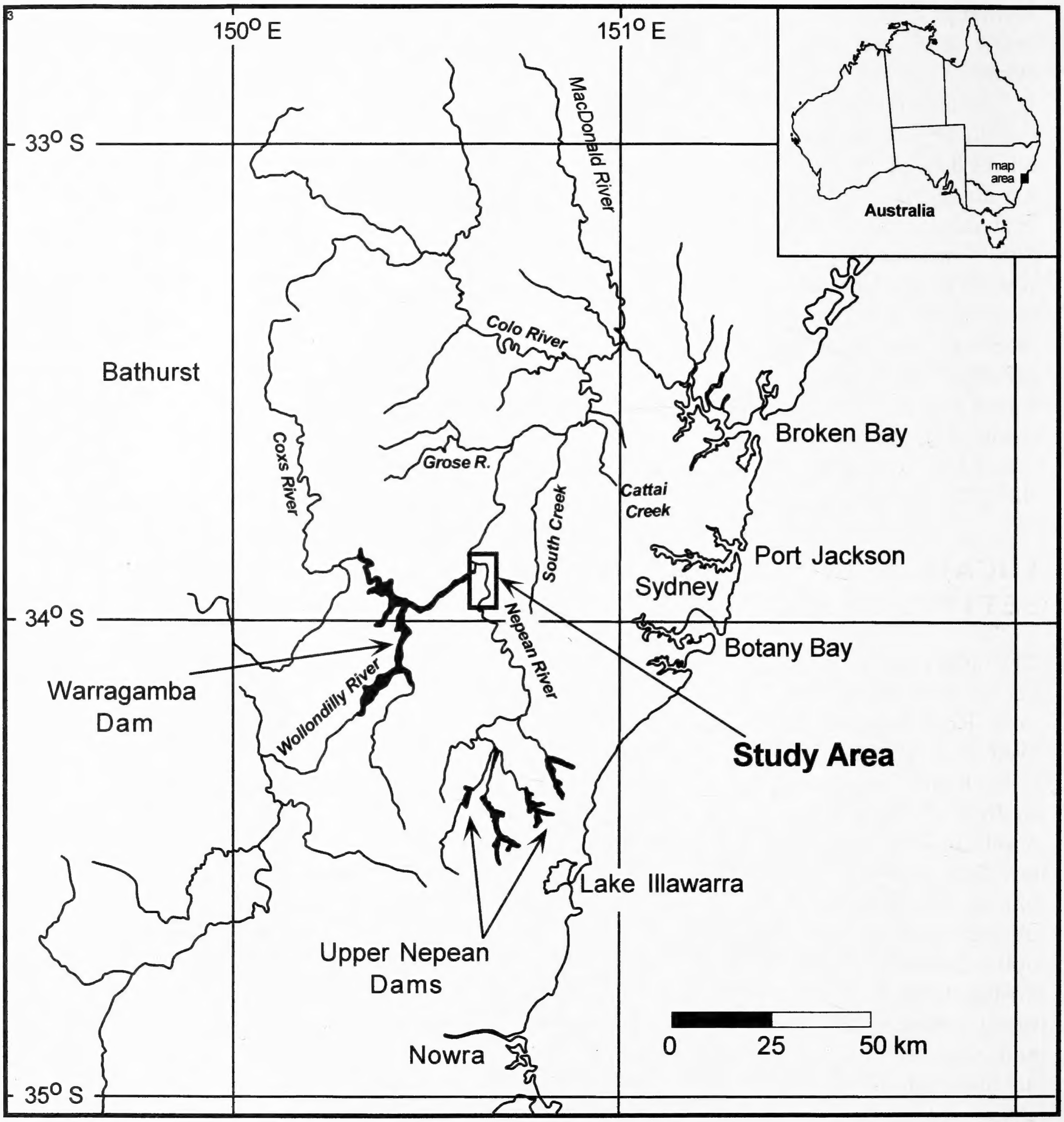

Figure 2: Location of the study area. Located between Wallacia Weir and Bents Basin approximately 50 km west south west of the Sydney CBD.

Any significant secular climate change that occurs in southeastern New South Wales has obvious repercussions for the hydrological regime of coastal river systems. Pickup (1976) recognised that the increase in mean annual rainfall since the late 1940s had resulted in an increase in the magnitude and frequency of floods in the Cumberland Basin west of Sydney however he did not show that the trends and interrelationships were statistically significant. Bell & Erskine (1981) were the first to show that the post 1946 increase in rainfall produced statistically significant increases in annual runoff and flood frequencies. Similarly, Hall (1927) examined the magnitude and frequency of floods at Windsor between 1795 and 1925 and concluded that the latter part of the 19th century was characterised by high rainfall and many floods in comparison to the early part of the 20th century.

Warner (1987a, 1987b) described these periods of higher than average and lower than average rainfall and flooding, as flood- and drought-dominated regimes respectively (commonly abbreviated to FDR and DDR). DDR are recorded from 1821 to 1856 and again from 1901 to 1948; while FDR are recorded from 1799 to 1820, from 1857 to 1900, and from 1949 to the present. Erskine & Warner (1988) indicate that the change in flood regime involves a significant variation in the number of floods of a given height class and that this variation in flood frequency may also be accompanied by a significant variation in flood height.

Recent work (see Kirkup et al. 1998) openly questions the validity of the FDR/DDR model and instead proposes that there is only enough reliable evidence to support a single, secular climatic change (i.e. the change to a wetter climate in the late 1940s). Flood frequency curves taken within the Wallacia Valley (Fig. 3) demonstrate the resulting increase in flood activity from this time.

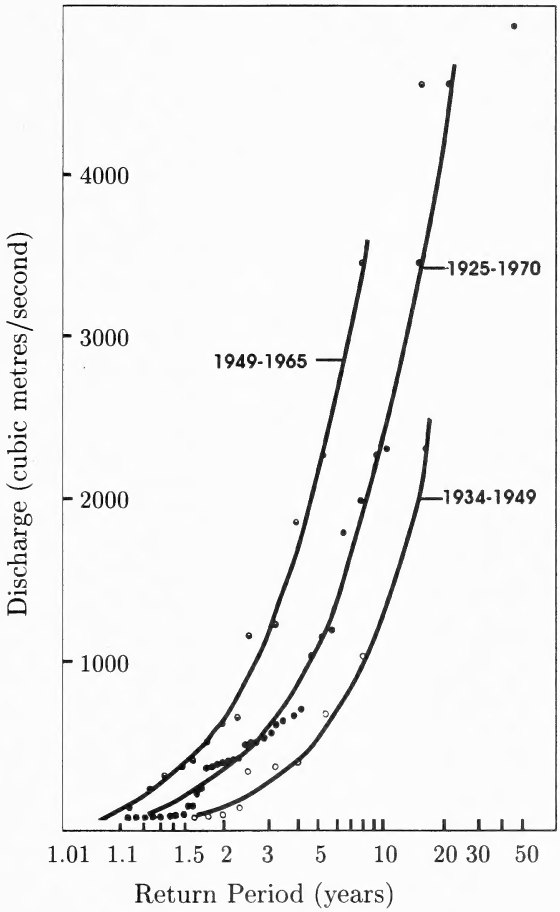

Figure 3: Flood frequency curves for the Nepean River at Wallacia indicating the increased flood activity between 1949 and 1965 relative to the period 1934 to 1949. From Pickup (1976, p.189). Source: Records of the Metropolitan Water Sewerage and Drainage Board.

HUMAN MODIFICATIONS TO THE STUDY AREA

The environment of the study area has been extensively altered in the 213 years since European settlement, with agricultural practice the primary impetus. The clearing of land for cropping and grazing has been almost total in its scale and examination of the 1947 aerial photographic record reveals only small tracts of riparian vegetation and other small pockets of bush-land in existence over the floodplain. Such extraction of riverbank vegetation removes its ability to contribute to bank stability. Vegetation contributes to soil slope stability by buttressing and arching, soil moisture modification, surcharge weight, and root reinforcement (Gray & Leiser 1982, Coppin & Richards 1990, Morgan & Rickson 1995). Root reinforcement is often considered the main effect (see Abernethy & Rutherfurd 1998) and tree roots have been found to contribute an average increase in soil cohesion of 5.2 kPa. Variation about this mean is significant due to differences in vegetation and soil characteristics (Morgan & Rickson 1995). As yet no study has been conducted to determine the appropriate values for the riparian trees of the Wallacia Valley.

The construction of Wallacia Weir in the early 1900s modified the entire length of the study area by converting a natural low-flow channel with water tumbling through a riffle and pool sequence, into a long, narrow lake up to 5 metres in depth and 50 metres in width. The weir was constructed by the Public Works Department to provide river frontage properties in the Wallacia Valley with a permanent water supply after completion of the Cataract, Avon, Cordeaux, and Nepean Dams reduced flows in the upper Nepean River (W.R.P. 1995). The only perceptible water movement during low flow periods results from wind waves (dam releases and freshes being the exception) which subsequently attack the pre-weir lower to middle bank region, causing widespread and extensive undercutting and the formation of toe scarps or notches at the permanent waterline (Hubble & Harris 1993). The series of events that lead to undercutting of the toe are described in Hubble & Hull (1996) and have been documented on many river systems (e.g. Petts 1979, Simons & Li, 1982, Thorne 1982, Warner & Paterson 1987, Hubble & Harris 1993). Toe erosion, which is mostly brought about by the presence of a weir, also makes the upper bank more likely to fail due to the removal of its basal support (Hubble & Harris 1993).

Since the 1960s some sections of channel within the study area were widened and deepened as large quantities of sand and gravel were removed for use in the construction industry (Warner 1983, Erskine 1997). Dredging not only excavates and widens the channel of itself but the consequent training of all but the largest flood flows within the channel's levees can lead to a further widening and deepening of the channel (Simon 1994). Prior to the inception of slope batter rules by the Department of Water Resources such changes to channel geometry resulted in steeper banks more prone to mass collapse. The widespread removal of riparian vegetation during the extraction process also facilitated the development of potentially unstable riverbanks. Widening of the channel also has the effect of exposing a larger portion of open water to wind thereby increasing the unimpeded wind fetch. The waves generated promote the formation of banks exhibiting undercut or toe scarp features (Hubble 1996).

In addition to the effects imposed upon the adjacent riverbanks, an enlarged channel inflicts morphological changes both upstream and downstream of the dredged site both during and after completion of dredging (Erskine 1990). The upstream and downstream ends of the dredged pool demonstrate localised increases in flow velocity as a result of the change in channel capacity. Erosion due to scour is concentrated in these areas.

AERIAL PHOTOGRAPHIC RECORD

The history of riverbank collapse in the second half of the 20th century has been determined by examination of the aerial photographic record. This record consists of seventy-nine aerial photographs that were taken in 1947, 1955, 1961, 1970, 1978, and 1992. Photography from the years 1947 to 1978 is from the Cumberland Plain series and was undertaken by the Lands Department of N.S.W. at an altitude of approximately 6000 m and at scales of 1:12 000 and 1:25 000. The 1992 photographs were undertaken for the Water Board at around 300 m above the river and yield a scale of 1:8 000. Documenting change from year to year is achieved by directly comparing images of the same area using a composite sequence of the same view. Two examples are presented here to highlight the occurrence of large-scale circular failures (Figs. 4 and 5).

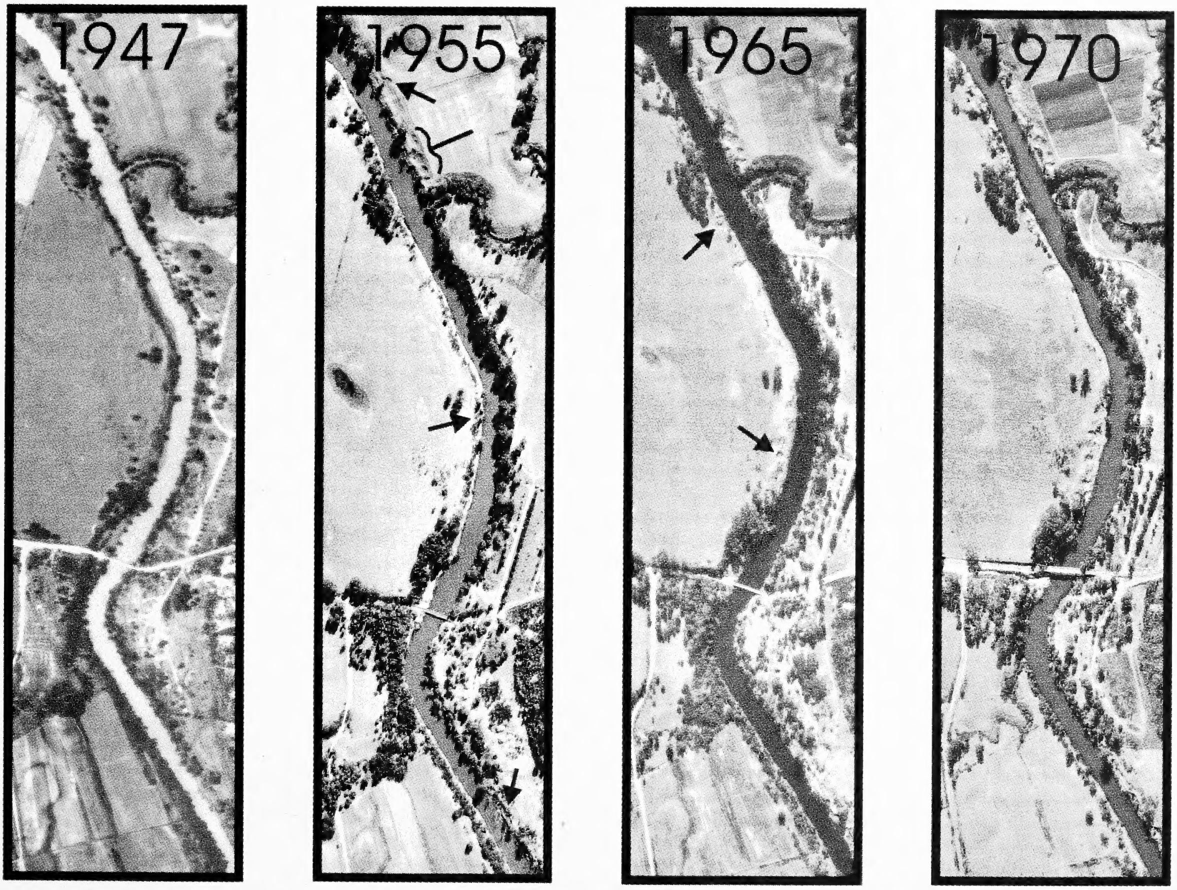

Figure 4: Aerial photographic composites immediately upstream of Wallacia Weir for the years 1947 to 1970. Arrows show new areas of large-scale circular failures. The largest number of new failures occurs on already devegetated banks between the 1947 and 1955 photographs.

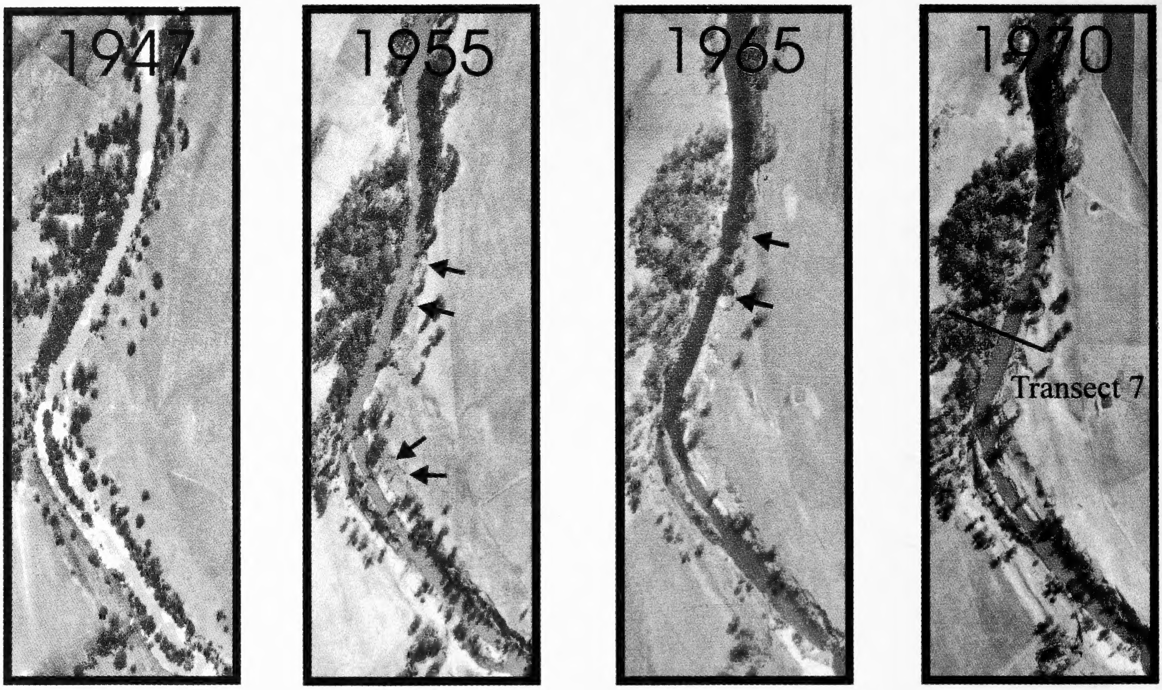

Figure 5: Aerial photographic composites approximately six kilometres upstream of Wallacia Weir for the years 1947 to 1970. Arrows show new areas of large-scale circular failures. The largest number of new failures occurs on already devegetated banks between the 1947 and 1955 photographs.

Examination of the 1947 photographs reveals the extensive clearance of riparian vegetation on both banks of the river. The occurrence of farming practices right up to the levee bank in many places has resulted in only isolated dense patches of vegetation or a thin strip of bush-land remaining close to the waterline. Large-scale circular failures are rare, although isolated occurrences were apparent.

In 1955, the first records after the onset of the wetter climatic period, circular failures are common. Many devegetated banks exhibit multiple failure scarps and although some failures were evident on lightly vegetated banks the vast majority of circular failures are present on banks cleared of vegetation prior to their collapse (see arrows Fig. 4). The number of failures apparent increases progressively through the 1961 and 1965 photographs by which time failure is widespread. New failure scarps are rare from the 1970 series onwards. This scenario is repeated over the length of the study area and in similarly devegetated areas of the Camden Valley (Hubble 1996). In figure 5 large circular failures are scarce in the 1947 images however through to the 1970 images a period of accelerated scarp formation is observed. The largely devegetated right bank is considerably more affected than the left bank. This observation was confirmed by field inspection of these banks (e.g. transect 7, Fig. 6).

The initiation of accelerated bank-collapse evident between the late 1940s and the 1955 photographic record corresponds exactly with an increase in both flood frequency and flood height. From 1937 to 1947 there were 8 recorded floods at Wallacia Weir at a mean height of 2.70 m. Between 1947 and 1955 there were 16 floods at a mean height of 5.08 m. All banks have clearly been subject to the same flood events.

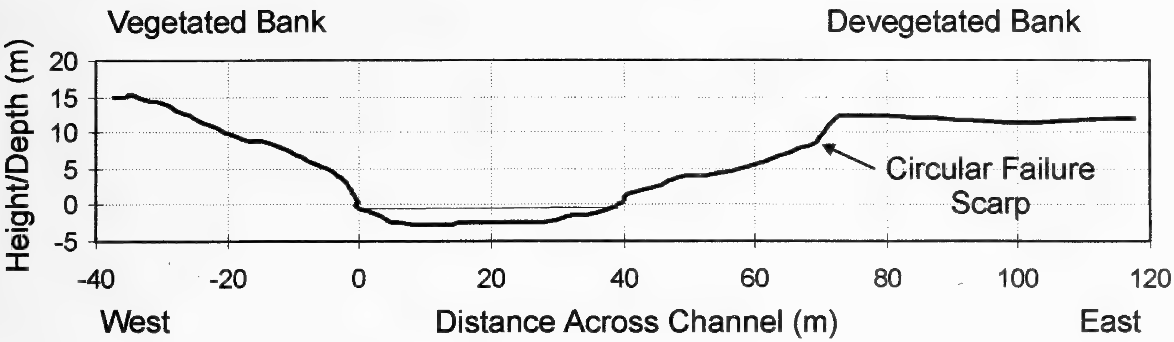

Figure 6: Transect seven illustrating differing bank morphology for vegetated and devegetated banks. A large failure slump evident on the devegetated right bank while the vegetated left bank remains intact. Location of transect line is shown on Figure 5.

It is unclear at what point sand and gravel extraction commenced within the study area although extraction was known to be occurring by 1968 (SPCC 1977). Erskine (1997) states that soil mining and minor sand dredging have occurred in the Wallacia reach of the Nepean River since the mid 1960s. The aerial photographic record indicates that the onset of the most severe mass collapse took place prior to 1955 and continued with some significance through the 1960s. As dredging activities within the study area largely post-date the onset of this excessive erosional period they cannot be considered as the initiator of the large-scale circular failures observed although dredging may have exacerbated these failures as suggested by Hubble (1997).

CURRENT BANK MORPHOLOGY

The morphologies of the river banks as they exist today were recorded by conducting eleven transect surveys at approximately equal intervals over the length of the study area. The overwhelming channel morphology exhibits very steep and quite high banks. In many places an incipient floodplain has developed below the level of the floodplain proper. Some banks present areas of exposed bedrock while mass failure of the type reported by Hubble & Harris (1993) occur over the entire length of the channel. There are three styles of bank erosion observed within the study area. They are: (1) Deep rotational failures; (2) Shallow Plane failures; and (3) Cantilever/slip failures at the water's edge. The average bank height recorded was 15.7 metres from the base of the channel to the floodplain. The average slope was 26 degrees from the base of the bank to the levee crest.

As demonstrated by the aerial photographic record mass wastage of riverbanks occurs primarily on those with the least vegetation cover. A clear example of the differing bank morphologies resulting due to vegetation cover is presented over transect 7 (Fig. 6). On the densely vegetated left bank a slope of 26 degrees is maintained despite the lack of basal support and the presence of a large (1.5 m) toe undercut. The devegetated right bank is characterised by a large rotational failure scarp, which has reduced the slope of the bank to 17 degrees.

A morphological process that is common throughout the study area is the erosion of the lower bank at the weir water line. This process is evident as either a toe-undercut or a toe-scarp and is probably due to the erosive power of wind waves on the weir-created lake (Hubble & Hull, 1996). The waterline morphologies of river banks presenting toe erosion are illustrated in Figure. 7. Fourteen of the 22 banks surveyed document this process. The largest tow undercut observed within the study area was 1.5 m.

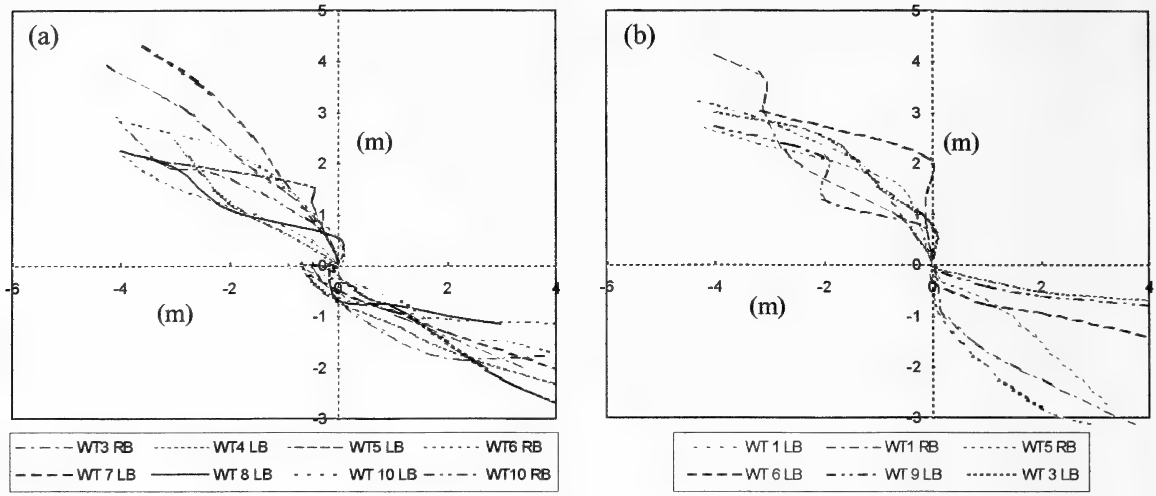

Figure 7: Waterline bank profiles illustrating (a) toe undercut, and (b) toe scarp formation. Fourteen of the twenty-four banks surveyed demonstrated one of these two morphologies.

GEOMECHANICAL ANALYSIS

The geomechanical analysis of riverbanks was undertaken using simple slope stability theory via a computer program (XSLOPE) based on Bishop's simplified method (see Bishop 1955). Critical failure circles were produced for a riverbank of average dimensions. The input variables were vegetation cover, toe erosion in the form of a scarp, slope angle and flood stage.

Vegetation cover was modelled by incorporating an additional cohesion into the soil strength. It is generally claimed that root systems contribute to soil strength by providing extra cohesion and that they have a negligible influence on the frictional component of strength (see Gray & Leiser 1982). The value used was 5.2 kPa. The root cohesion was incorporated in a "root mat" to a depth of 3 m into the bank as such a thickness represents a conservative estimate, based on field observations throughout the study area. Toe erosion was modelled by changing the morphology of the bank accordingly. Flood stage was modelled for two conditions: (1) low-flow, when the water level in the channel is at the height of the weir and remains so within the bank; and (2) immediately post-flood with a draw-down condition, where the banks are fully saturated and the water level within the channel is at the low-flow level.

The slip-circles with the minimum factor of safety for both the vegetated case and the unvegetated case using average morphological dimensions are presented in Figure 8. Clearly the removal of vegetation from the river banks significantly reduces the factor of safety from one of stability to an unstable state, assuming the soil is saturated. In the low flow condition the bank is stable irrespective of vegetation cover. The failure of a riverbank with average morphology and soil properties requires both saturated and devegetated conditions. Neither condition is able to cause bank failure in isolation.

Channel dredging is often associated with an increase in slope angle due to removal of the lower bank region. Table 1 shows clearly the effect on a bank's factor of safety of increasing the slope angle for a devegetated bank subject to rapid drawdown. The critical bank slope occurs between 20 and 25 degrees. Considering the average bank angle within the study area is 26 degrees it is not surprising so many mass failures occur on devegetated banks.

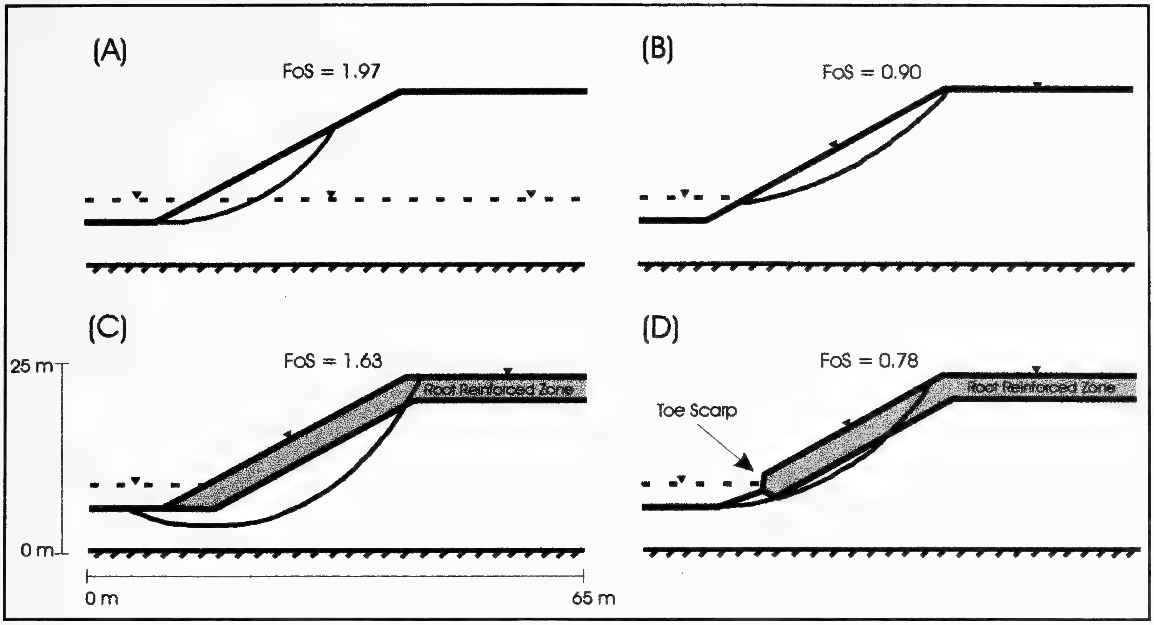

Figure 8: Minimum slip circles developed for a riverbank of average height and slope angle. (a) devegetated and dry; (b) devegetated and wet; (c) vegetated and wet; (d) vegetated and wet with 2 m toe scarp. For a saturated bank the difference between the vegetated and devegetated states is a FoS of 1.63 compared to 0.90. For a bank with a toe notch present even the vegetated case can present as unstable (FoS 0.78).

Slope Angle (°)	FoS
15	1.48
20	1.36
25	0.97
30	0.74

Table 1: The factor of safety due to slope angle. All other parameters are the same.

A bank-toe profile presenting either a toe notch or undercut of the dimensions observed within the study area also has a significant impact on the factor of safety of a slope. The FoS of a saturated, vegetated bank with a 2 m high toe scarp is 0.78, compared to 1.63 for the same slope with basal support present.

SUMMARY AND CONCLUSIONS

Through historical and geomechanical analysis it is possible to assess the potential causes of the accelerated riverbank collapse evident within the Wallacia Valley over the latter half of last century. Examination of the aerial photographic record reveals that the onset of large-scale bank collapse took place between 1949 and 1955 and occurred predominantly on banks devoid of vegetation. From the 1970 photographic series onwards further circular failures were rare. The flood record from Wallacia Weir describes a similar account, with a massive increase in flood activity from 1949 compared to the preceding years. Clearly the saturation of the banks associated with these discharges and the subsequent pore-pressure differences resulting from rapid-drawdown have resulted in a critical loss of stability on banks cleared of strength-enhancing vegetation. Geomechanical modelling shows that vegetated banks are able to resist collapse by an increase in the apparent cohesion of the soil brought about by root permeation to depths of 3 metres. A riverbank of average dimensions within the Wallacia Valley describes a critical loss of stability when strength-enhancing roots are removed from the upper layers of the soil, however the clearing of vegetation in itself is not sufficient cause for collapse. The bank must also be experiencing a positive pore-pressure difference associated with rapid draw-down. This is consistent with the fact that although banks had been cleared of vegetation many years prior to the 1947 photographs it was not until the accelerated level of flood activity after this date that large scale circular failures became common.

Extraction of sand and gravel, while recognised as a significant contributor to loss of riverbank stability through an altering of bank morphology, has been excluded as a primary cause of large-scale bank collapse within the Wallacia Valley. Dredging of the channel did not begin until the late 1960s, post-dating the beginning of the most energetic period.

The erosive power of wind waves on a weir-created lake causes a destabilising action on a riverbank by removal of its basal support. On a bank of otherwise average morphological dimensions a 2 metre toe notch has the ability to undermine the increased factor of safety brought about by the presence of vegetation thus rendering what would otherwise be a stable riverbank, likely to fail. Toe notches of 2 metres are frequently observed throughout the study area. It is likely therefore that the building of Wallacia Weir has contributed to bank collapse within the valley.

The long-term stability of the channel and its subsequent incision into the sandstone and shale basement has resulted in banks that are at or near their limit of stability. With vegetation present the additional cohesion active within the upper soil layers is sufficient to keep such banks from collapse. With the additional cohesion removed these banks are at the mercy of large pore-pressure differences inherent after flood activity.

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Heat Shock Events, Inhibition of Seed Germination and the Role of Growth Regulators in Stress Alleviation

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Abstract: The timing of heat stress after sowing is crucial in the success of pearl millet crops. Several heat shock events were evaluated and the impact of seed treatments on germination was investigated. Segmenting seed treatments into phases and sequencing growth regulators with water was also evaluated. Seven growth regulator-based seed treatments were applied to pearl millet seeds with the goal of improving the germination and early seedling growth under these heat shock events. Both gibberellic acid (GA_3) and kinetin were sequenced with water in one or two cycles (growth regulator/water) for 4 hours. Otherwise, seeds were soaked in water alone for 4 hours. Heat shock (46°C) was administered on the first three days after sowing seeds, the fourth, the fifth or sixth day and in alternating form (shock/no shock). Results revealed that sequencing growth regulators with water advanced germination to a greater extent than growth regulators alone. Seed treatments increased the speed of germination over controls and the first three days after sowing were more sensitive to heat shock than days 4, 5 and 6. The physiology of seed response to heat shock is discussed.

Keywords: heat, germination, growth, stress

INTRODUCTION

Pearl millet (*Pennisetum gluacum* L. R. Br.) is a staple grain source in the arid tropics and subtropics. It is similar to maize in its varying uses and acts as both a food and fodder source. Environmental stresses, primarily limited moisture content and supra-optimal temperature, restrict successful seed germination and plant establishment of pearl millet in arid and semi-arid regions of the world. Soil temperature is an important physical property that affects evaporation from the soil surface, soil moisture, seed imbibition (McCarty, 1992; Hardegree, 1994; Horne and Kahn, 2000), plant development and water movement (Mathan and Natesan, 1989). The temperature of the first two to three centimeters of the soil, which constitutes the seedbed of pearl millet, periodically reaches levels considerably higher than air temperature (Laude et al., 1952; Noe and Zedler, 2000) thus affecting seed performance. Studies on the effect of temperature on germination in the field are somewhat difficult to implement and so investigations are usually done in water baths or sand tables set at different temperatures (Clegg and Eastin, 1978). A seed is, however, usually exposed to varying temperatures (Cornett et al., 2000) during the course of the day ranging anywhere between minimum, optimum or maximum temperatures for germination, changing as time goes by (Flower et al., 1990). The faster germination and emergence occur, the less the time a seed will be exposed to such fluctuations and the more likely it is to succeed in emergence and plant establishment.

Previous studies on the germination of pearl millet and sorghum have shown seed priming treatments to improve germination under drought stress, but not under heat stress (Al-Mudaris and Jutzi, 1997). The objective of this investigation was to test the influence of timing of heat shock on germination of three pretreated and stored pearl millet genotypes and to test the impact of various heat shock timings/events on treated and untreated seeds.

MATERIALS AND METHODS

Heat Shock During the First Three Days After Sowing

The seeds of pearl millet variety Nokha, a local landrace grown by farmers near Nokha, Bikaner, in the Indian state of Rajasthan, were treated in one of seven ways as shown in Table 1. Nokha is a photosensitive pearl millet hybrid that is used for food and fodder (International Crops Research Institute for the Semi Arid Tropics ICRISAT, personal communication). Seed lots were obtained from ICRISAT and tested following International Seed Testing Association (ISTA) guidelines (ISTA, 1993) and showed germination percentages of 98%, 1000 seed weight of 7.4 g, moisture content of 14% and viability (tetrazolium) of 99.3%.

Seed treatments were administered by wrapping seeds in cheese cloth, tieing the end with a string and lowering them into the treatment solution/s. Growth regulators GA_3 and kinetin (Sigma Chemical, USA) were dissolved in 5% acetone and mixed with distilled water to achieve 200 ppm (200 mg/l) of GA_3 and kinetin, respectively. Water-soaking involved distilled water with 5% acetone added to it to account for any possible acetone effect. In sequential treatments of growth regulators and water, pouches were lowered in one solution, taken out and rinsed in distilled water and lowered in the next solution. All treatments took place at ambient temperatures of 22–25°C under daylight conditions. Relative humidity (RH) in the laboratory was 51% (Schulter Thermohygrograph, Germany) and all treatments were conducted in 3-litre glass beakers.

After treatment, seeds were blotted on Whatman No. 1 filter paper and dried back in a reverse cycle cabinet (Conviron Industries, Canada) at 25°C for 16 hours (h). Thereafter, they were stored in paper bags at 20°C and 50–55% RH for 4 months in a dark seed store. At termination of the storage period, seeds were retrieved and sown in 1-litre polystyrene trays between two layers of creased, moistened filter paper (Schuess, Germany). Two hundred seeds were sown per tray and each treatment combination replicated 4 times (7 seed treatments × 4 heat shock scenarios × 4 replicates). Trays were arranged in a Randomized Complete Block Design (RCBD) inside growth chambers (Hereaus Voetsch, Germany). Germination was then undertaken at one of four heat shock regimes (Table 2). These were designed to expose the seeds to a heat shock of 46°C either on the first, first and second, or first, second and third days after sowing (DAS) to test post-shock responses.

Treatment	Description
W	Wet Control: Seeds soaked for 4 hours (h) in distilled water.
W-K-1	Seeds soaked for 1 h in water, 1 h in kinetin (200 mg/l), 1 h in water and, finally, 1 h in kinetin.
W-K-2	Seeds soaked for 2 h in water then for 2 h in kinetin.
K	Seeds soaked for 4 h in kinetin.
W-G-1	Seeds soaked for 1 h in water, 1 h in GA_3 (200 mg/l), 1 h in water and, finally, 1 h in GA_3.
W-G-2	Seeds soaked for 2 h in water then for 2 h in GA_3.
G	Seeds soaked for 4 h in GA_3.

Table 1. Soaks with growth regulators used to treat Nokha pearl millet seeds.

Regime	Details
HS 0	No heat shock (Control): Seeds germinated at a constant 30°C temperature for the whole 10 day period.
HS 1	Heat shock administered on the day of sowing with a temperature of 46°C for 24 h (total = 24 h). Thereafter, a constant 30°C was used till 10 DAS.
HS 12	Heat shock (46°C) administered on the first and second days after sowing (total = 48 h). Thereafter, a constant 30°C was used till 10 DAS.
HS 123	Heat shock (46°C) administered on the first, second and third days after sowing (total = 72 h). Thereafter, a constant 30°C was used till 10 DAS.

Table 2. Heat shock regimes applied to Nokha pearl millet seeds on the first 3 days after sowing (DAS).

Germination counts were taken daily for 10 days and from them the final germination percentage (FGP), mean germination time (MGT) and coefficient of velocity of germination (CVG) calculated. The CVG gives an indication of the rapidity of germination (Jones and Sanders, 1987). It increases when the number of germinated seeds increases and the time required for germination decreases. Theoretically, the highest CVG possible is 100 and would occur if all seeds germinated on the first day. The fresh weight of plumule + radicle after separation from the seed (hereafter termed FWSD) was averaged for 20 seeds and recorded. All data were exposed to an analysis of variance (Weber and Antonio, 1999) after arcsine transformation of germination percentages (Yang et al., 1999; Houle et al., 2001), and mean separation conducted using the General Linear Model (PROC GLM) of the SAS® statistical package (SAS, 1989) at 5% probability.

Heat Shock on the Fourth, Fifth and Sixth Days After Sowing

Due to the fact that the first five to six days after sowing are the most sensitive to temperature fluctuations, in as far as the success or failure of germination is concerned, this test was designed to impose heat shock in the second half of this phase, namely days 4, 5 and 6 after sowing. The pearl millet hybrid ICMH 356 obtained from ICRISAT was treated in the same manner as Nokha in the previous experiment and exposed to four heat shock regimes (Table 3). ICMH 356 had germination, moisture and viability percentages corresponding to those of Nokha and a 1000 seed weight of 10 g. It is a short, grey coloured hybrid that is resistant to downey mildew and used as a source of grain. The same germination and growth parameters as above were employed. Statistical arrangements were similar to those of the first experiment.

Regime	Details
HS 0	No heat shock (Control): Seeds germinated at a constant 30°C temperature for the whole 10 day period.
HS 6	Heat shock (46°C) administered on the sixth day after sowing (total = 24 h). Thereafter, a constant 30°C was used till 10 DAS.
HS 56	Heat shock (46°C) administered on the fifth and sixth days after sowing (total = 48 h). Thereafter, a constant 30°C was used till 10 DAS.
HS 456	Heat shock (46°C) administered on the fourth, fifth and sixth days after sowing (total = 72 h). Thereafter, a constant 30°C was used till 10 DAS.

Table 3. Heat shock regimes applied to ICMH 356 pearl millet seeds on the fourth, fifth and sixth day/s after sowing (DAS).

RESULTS AND DISCUSSION

Heat Shock During the First Three Days After Sowing

When treatments were pooled over heat shock regimes, all six growth regulator seed treatments improved germination characteristics over controls. Seeds soaked in growth regulators germinated to a higher extent and at faster rates than untreated seeds. This was evident in the FGP, MGT and CVG values observed (Table 4). Sequencing growth regulators with water did not seem to affect the final germination percentage since hormonal treatments were similar to each other in this regard. Generally, GA_3 treatments gave earlier germination patterns that ended sooner. They also gave higher CVG values than controls, and, in some cases, than kinetin soaks. The fresh weight of seedlings was significantly affected by seed treatment. Growth regulator treatments induced larger and, thus, heavier plumules and radicles to form. The best enhancement of seedling growth was observed in seeds treated with W-G-2. Second best was W-G-1 followed by W-K-1 and W-K-2. Sequencing improved the performance of growth regulators in inducing growth (Table 4).

Heat shock regimes pooled over treatments affected the FGP and FWSD, but had no apparent effect on the speed of germination (Table 4). Heat shock in all three forms gave lower FGP values than the 30°C no-shock treatment. The longer the duration of this shock, the weaker and, thus, lighter in weight, were the seedlings produced (Table 4). Interactive analysis of seed treatments and heat shock regimes confirmed this (data not shown for brevity). Heat shock reduced germination and seedling growth, seed treatments improved performance, and sequencing was superior to continuous treatments.

Heat Shock on the Fourth, Fifth and Sixth Days After Sowing

Again, all six growth regulator treatments gave better germination characteristics, in terms of percentage and speed, than the water-soaked seeds (Table 5). Sequenced GA_3 increased the FGP and CVG and reduced the MGT greater than kinetin or unsequenced GA_3. Kinetin, on the other hand, was not affected by sequencing with all three kinetin treatment forms advancing germination over controls. The FWSD was not affected by seed treatment. An exception to this was lower FWSD values for seeds treated with GA_3 for 4 h (Table 5). Heat shock at all three timings significantly reduced the germination percentage but did not affect germination speed.

When heat shock was administered on the sixth day after sowing, it significantly reduced the fresh weight of seedlings to 140.3 mg from the 145.1 mg control (Table 5). However, as the timing of heat shock approached 4 DAS, and as its duration increased (HS 456), the FWSD dropped to 71.8% of that of the control (calculated from Table 5). The earlier the heat shock and the longer its duration, the less developed were the seedlings.

The two experiments reported above indicate that the heat sensitive phase of pearl millet germination is mainly in day 1 rather than days 3–5. The earlier the heat shock after sowing, the more its negative effects. Seed treatment with growth regulators helps in the advancement of seed germination. That GA_3 treatments induced earlier and more synchronous germination patterns is consistent with previous knowledge about the action of growth regulators (Eastwood et al., 1969; Hof and Saha, 1999; Rock and Ng, 1999; Christianson, 2000). It also confirms the results of Al-Mudaris and Jutzi (1997) where GA_3 was superior to kinetin in this advancement. This reveals that the storage of growth regulator-treated seeds seems not to adversely affect their performance.

	FGP (%)	MGT (day)	CVG	FWSD (mg)
Seed Treatment				
W	62.8 b	2.9 a	34.3 c	103.3 f
W-K-1	80.9 a	2.3 b	43.7 c	115.3 c
W-K-2	76.2 a	2.1 bc	46.8 b	110.3 d
K	80.3 a	2.0 c	50.0 a	108.6 de
W-G-1	77.8 a	2.0 c	48.6 a	119.5 b
W-G-2	80.3 a	2.1 c	47.9 a	130.8 a
G	77.8 a	2.0 c	50.0 a	104.9 ef
Heat Shock Regime				
HS 0	85.5 a	2.1 a	46.8 a	132.0 a
HS 1	70.1 c	2.3 a	44.0 a	121.0 b
HS 12	77.6 b	2.2 a	46.4 a	109.0 c
HS 123	73.0 bc	2.2 a	46.4 a	91.5 d

Table 4. Effect of growth regulator seed soaks and heat shock regimes on germination and growth parameters of Nokha pearl millet. Seed treatment regimes are as shown in Table 1. Heat shock regimes are as shown in Table 2.

Means of treatment effects in columns followed by similar letters are not significantly different (alpha=0.05). The same applies to the means of heat shock regimes.

FGP: Final Germination Percentage, MGT: Mean Germination Time, CVG: Coefficient of Velocity of Germination and FWSD: Fresh Weight of Seedling (plumule + radicle).

	FGP (%)	MGT (day)	CVG	FWSD (mg)
Seed Treatment				
W	68.7 d	3.8 a	26.5 c	129.0 a
W-K-1	90.0 b	3.0 bc	33.3 b	131.6 a
W-K-2	87.5 b	3.0 bc	33.3 b	129.4 a
K	90.0 b	2.8 c	34.3 b	129.5 a
W-G-1	93.4 a	2.0 d	48.9 a	129.5 a
W-G-2	92.8 a	2.0 d	50.0 a	130.9 a
G	78.7 c	3.1 b	32.2 b	115.8 b
Heat Shock Regime				
HS 0	88.0 a	2.7 a	37.1 a	145.1 a
HS 6	85.5 b	2.8 a	37.1 a	140.3 b
HS 56	85.0 b	2.8 a	36.8 a	122.2 c
HS 456	85.0 b	2.8 a	36.5 a	104.3 d

Table 5. Effect of growth regulator seed soaks and heat shock regimes on germination and growth parameters of ICMH 356 pearl millet. Seed treatment regimes are as shown in Table 1. Heat shock regimes are as shown in Table 3.

Means of treatment effects in columns followed by similar letters are not significantly different (alpha=0.05). The same applies to the means of heat shock regimes.

FGP: Final Germination Percentage, MGT: Mean Germination Time, CVG: Coefficient of Velocity of Germination and FWSD: Fresh Weight of Seedling (plumule + radicle).

It is known that sufficiently high temperatures can inhibit germination or mitosis in non germinated seeds (Haber and Luippold, 1960) and induce stress and heat shock protein production (Hamilton and Coleman, 2001). Also known is that various forms of stress induce the production of abscicic acid (ABA) (Sebanek, 1992; Jacobs, 1998). Accordingly, studies on the interaction between growth regulators and seed germination have shown that cytokinins overcome the inhibitory action of abscisic acid (Thomas et al., 1975) and that ABA reduction leads to a changed hormonal balance (Farnsworth and Farrant, 1998). The application of exogenous GA_3 has also been proven to reverse physiological inhibition of seed germination (Kepczynski and Knypl, 1988) albeit on a species-specific basis (Arnold et al., 1996). The inhibition of seed germination in response to heat stress may have been the result of high ABA levels, low GA_3 and cytokinin levels or both. That growth regulator applications advanced germination over controls may be seen as a re-balancing of this hormonal shift in favour of germination promoters.

Sequencing growth regulators with water proved superior to constant growth regulator soaks in advancing germination. It may have evoked this effect through a late activation phase (Kepczynski and Knypl, 1988) where a lag phase is witnessed upon transformation from the growth regulator to water.

Bush (1996), studying the effect of GA_3 on wheat aleurone cells, found that GA_3 induced a steady-state increase in cytosolic calcium which is important for the primary response to GA (the production and secretion of hydrolytic enzymes) and subsequent germination. This increase was initiated within a few minutes of treatment with GA and was fully developed after 30–90 minutes. If this were the case in pearl millet, it would probably mean that the peak action of GA_3 existed in the first one to one and a half hours after initial soaking, and that the remaining treatment period (total treatment period was 4 h) acted in a purely physical form through loosening of the seed coat.

The effects of heat shock on germination of sorghum and millet seeds were clearly negative. Not surprisingly, 46°C given at any one of the first six days after seed sowing reduced germinative performance in the genotypes studied. The first day after sowing seems to be the most sensitive phase to heat shock, and consequently, when stressed at this particular time, seeds respond with a drastically reduced germination. Coincident with this reduction was the oozing of brown exudates from the seed and eventual deterioration. This was particularly clear in earlier stages of heat shock application. Similar exudate oozing has been reported in maize, rice, sorghum, soybean, sunflower, wheat and groundnut (Sweet and Bolton, 1979). This would mean that once reaching a particular hydration level - as happens after 25 h of imbibition - heat shock may prove deleterious to germination not only by affecting its physiological mechanism, but by inducing microbial deterioration. An earlier observation by Hunter and Erickson (1952) is the covering of seeds with mycelia of fungi and eventual decay in the soil environment under moisture stress conditions. Clearly, then, the earlier the heat shock, the more negative are the carry-over and side effects. This also agrees with the moisture stress scenarios reported by Al-Mudaris and Jutzi (1997) where drought on the first day after sowing carried effects over to post-stress stages and those of drought, and salinity stress studies (Olsson et al., 1996; Howard and Mendelssohn, 1999). Growth regulator treatments helped in alleviating heat shock, probably, as mentioned, by altering the hormonal balance between inhibitors and promoters of germination. However, even though other reports (Haber and Luippold, 1960) have confirmed this, they also state the possibility of loss of GA_3 activity at high temperatures.

Garcia-Huidoboro et al. (1982) reported failure of *Pennisetum typhoides* seeds to germinate at 47/16°C, and so the range of hormonal action seems to be limited. The speed of germination decreased as heat shock duration increased or its application shifted to earlier days after sowing. Although the response of seeds to temperature, with respect to germination speed, is linear up to the optimal germination temperature (Mc Ginnies, 1960; Hsu et al., 1984), it appears to drop as soon as the supra-optimal temperature range is entered. The base temperature for *Pennisetum americanum* seed germination has been reported to be around 8 to 11.5°C (Mohamed et al., 1988). Lines and hybrids of sorghum and pearl millet that are tropically adapted have been reported to have different base temperatures than temperately adapted ones (Maiti, 1996).

Our results are in line with those of Martin et al. (1935) and Macchia and Dinelli (1989) where temperatures higher than 40°C reduced sorghum germination due to a reversible strain which results from a reduction in the rate of chemical reactions and physical processes at extreme temperatures (El-kholy et al., 1997) and an altered moisture uptake by the seed (Seong, 1989). An interesting result in our work is that day 1 after sowing is more sensitive than subsequent days. Also, when seeds experience alternating temperatures in which the mean temperature exceeds the optimum, germination decreases with increase of mean temperature (Murdoch et al., 1989).

That optimal temperatures for germination and seedling growth differ is also important. Whereas germination may respond more favorably to 35°C, seedling growth is optimal at 25°C (Kader, unpublished data). This may be due to the fact that temperature is likely to affect seedling establishment by influencing the balance between photosynthesis and respiration (Bannister, 1978) in addition to coleoptile elongation (Carberry and Campbell, 1989) in a different way than that of its effect on the physiological induction to initiate germination. This supports the hypothesis of Ross and Hegarty (1979) that the process of the initiation of cell elongation during germination is under a separate metabolic control from elongation itself. The fact that heat shock reduced seedling growth may be due to the direct effects of temperature or to indirect side effects showing up later, even when seedlings are transported to more neutral temperatures as reported for *Phaseolus acutifolius* and *Phaseolus vulgaris* seedlings (Udomprasert et al., 1995).

CONCLUSIONS

In conclusion, it appears that growth regulator seed treatments may aid in mitigating the effects of heat shock on pearl millet seeds. The 46°C shock applied in this investigation lies close to the maximum temperature reported for other pearl millet cultivars (42.1 to 45.6°C) (Mohamed et al., 1988). In the field, the soil derives its heat from two main sources: direct radiation from the sun and by conduction from the interior of the earth. The soil surface temperature is lowest in the early morning and highest in the early afternoon (Maiti, 1996). If the seed escapes the first phase of its life in the seedbed (post day 1) without major injuries through oozing and deterioration, a better stand of plants may be expected.

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Factors in the Use of Breast Screening for Effective Secondary Prevention

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Abstract: Although Australia has set up a breast screening program in each State and a National Breast Cancer Centre, there is a lack of understanding of mammography over a wide range of the community, both women and men, about its objectives, limitations and requirements for effective secondary prevention of breast cancer. Therefore it seems desirable to examine the criteria for selection of a disease for screening as established by the World Health Organisation and discuss these criteria in their applications to screening for breast cancer. The presentation is made in the light of the Australian system and what each criterion realistically implies. With regard to the marginal cost per year of life saved calculated for a range of different screening strategies for age groups and screening frequencies it appears that the Australian strategy (age 50–69 biennially) compares very well with the most effective screening strategy.

Keywords: Breast screening, mammography, Australia

INTRODUCTION

The criteria for selection of a disease for screening have been established by the World Health Organisation as listed below. The following report discusses the case of breast screening in accordance with these criteria.

- The condition should be an important health problem;
- the condition should have a recognisable latent or early symptomatic stage;
- the natural history of the condition from latent to declared disease should be adequately understood;
- there should be an accepted treatment for patients with recognised disease;
- there should be a suitable test or examination;
- tests should be acceptable to the population;
- there should be agreed policy of whom to treat patients;
- there needs to be facilities for diagnosis and treatment;
- the cost of case funding should be economically balanced in comparison to the entire cost of medical care as a whole; and
- testing should be a continual process.

BREAST CANCER - A SIGNIFICANT HEALTH PROBLEM

Breast cancer is the second most common cancer amongst Australian women and the most common cause of death from cancer (29 per 100,000 in 1991 according to Australian Bureau of Statistics, 1993). Lifetime (0–74) risk of developing breast cancer is 1 in 16 and the likelihood of dying from breast cancer before 75 is 1 in 44 (Australian Cancer Society, 1993). Incidence of, and mortality from, breast cancer increases with age. The risk (Australian Cancer Society 1993) of developing cancer at age 30 is estimated as 1 in 2000, at age 50, 1 in 55, at age 74, 1 in 14. Established major risk factors include age, family history of breast cancer, prior breast cancer, benign breast disease, endogenous endocrine factors (eg age at menarche), age at birth of first child, age at menopause and radiation exposure. Other proposed but incompletely resolved risk factors include exogenous hormone exposure (eg oral contraceptive use), oestrogen replacement therapy and environmental factors including diet (Henderson 1997, Hoffman 1993). The main relative risk factors have been tabulated relative to all cases (Hoffman 1993).

EARLY SYMPTOMATIC STAGES AND THEIR SIGNS (DIRECT AND INDIRECT)

Breast cancer has an early non-palpable, detectable stage arising mainly in milk ducts (and sometimes lobular neoplasia may be associated with intraductal carcinomas) where calcium hydroxyapatite deposits from transformed and necrotic epithelial duct cells can be revealed as the earliest useful indication by soft X-rays used in mammography. Expert radiologist diagnosis is needed for interpretation between these signs of benign and malignant lesions. Mammographic screening is capable of detecting cases through both "direct" and "indirect" signs. "Direct signs" include palpable mass, nipple discharge, nipple or skin retraction, erythema and dimpling. "Indirect signs" include the presence of characteristic microcalcifications (Wolfe 1990, Thomas et al. 1993), often the early sign of possible tumour.

As methods of detection continue to improve such as in imaging, better film and other technologies to aid mammography, there has been further accumulation of experience with minimal breast cancer and improved effectiveness in recent years. The most appropriate measure for assessing changes in mortality rates is the age-standardised mortality rate. In the recent Australian Federal Government Year 2001 Report on Government Services (2001) the section on Breast Cancer Screening gives data on this parameter. In Australian screening programs there has been only a relatively small reduction in the number of deaths from breast cancer from 1994 to 1998 after the increase from 1987 to 1994 but, taken in association with population growth there is a significant effect on the age standardised mortality rate. That rate has declined from a peak of 27.2 per 100,000 women in 1989 to 23.0 in 1998 and "the decline appears to be strong and consistent from 1994 onwards". In that period screening participation has increased plus the benefits of improved imaging and quality control. In populations of breast cancers which are being diagnosed through mammographic screening programs as many as 50–60% of suspected cancers detected are less than 10mm in diameter or are "in situ" and are diagnosed as a result of a specific abnormality detected at screening. After the second stage of the screening process these may be considered to represent a probable malignancy. The pathway for mammographic screening and assessment and subsequent routine rescreening is shown in Figure 1 (courtesy of the NSW Breast Cancer Institute and the Australian Institute of Health).

Mammographic film reading is done utilising dual reading of all screened films independently by two screening radiologists. The need to have two readers has been shown to be important in early trials of breast screening. As an example of the significance, it was found in the initial Scotland Breast Screening Program that in the first 18 months of the program approximately twenty percent of cancers were detected by only one of the two readers (Kirkpatrick 1991). The particular cases, after being reviewed, revealed that these were very early lesions with subtle presentation. The cost of having two readers is a cost-effective component to yield the desirable level of the marginal cost per year of life saved (MCYLS) discussed in a later section of this paper. The cost per woman screened for Breast-Screen Australia is approximately \$100 per woman. (Report on Government Services 2001).

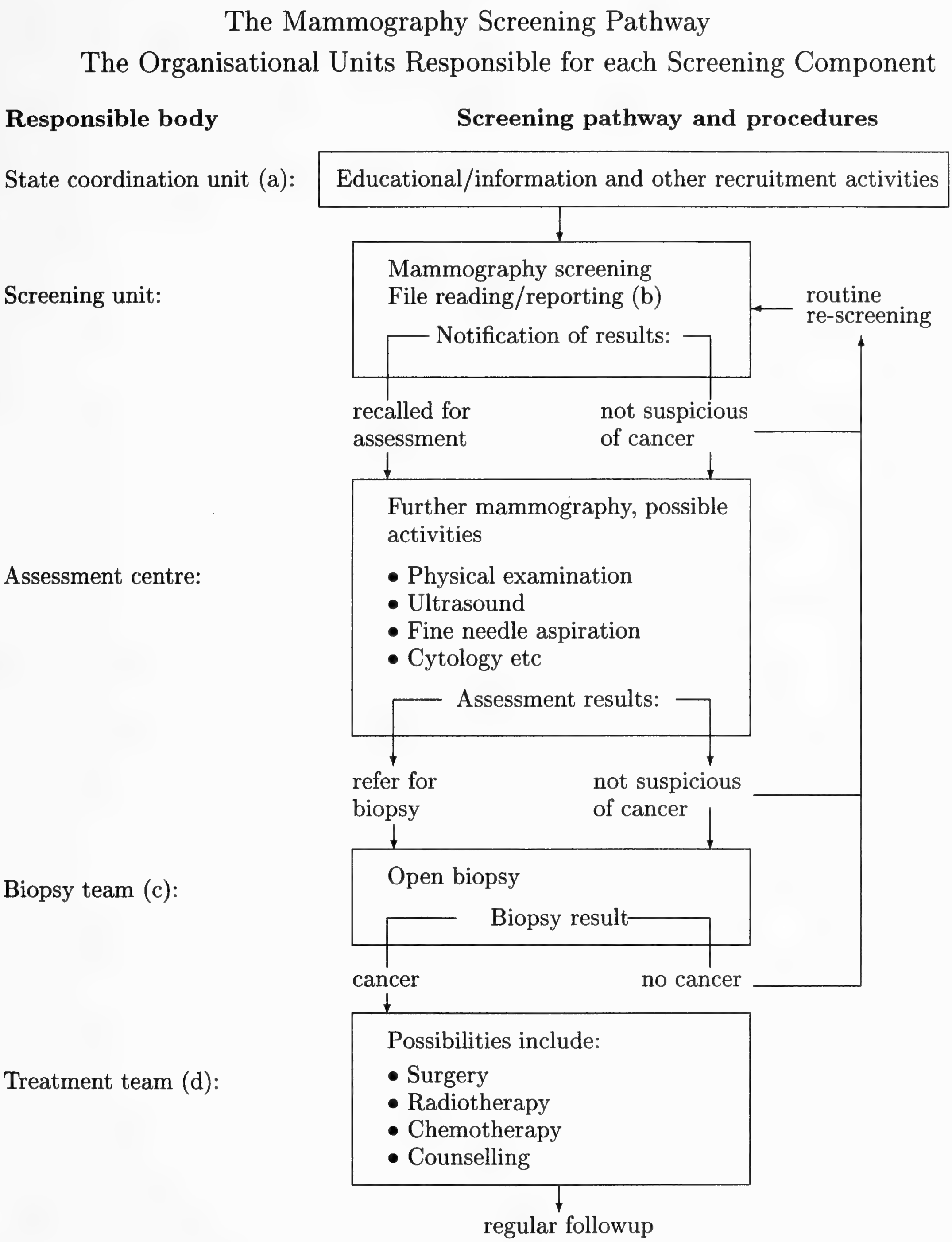

Figure 1: Pathway for mammographic screening and assessment and subsequent routine rescreening. (a) Additional functions of State coordination unit. (b) Film reading/reporting may be carried out by the screening unit or the assessment centre, depending on local requirements. It is vital that the film reader receives routine feedback on the results of the assessment. (c) The biopsy team may be an element of the assessment centre or may be part of the treatment team. (d) The treatment team may be a specialised breast cancer unit or usual medical centre. (Courtesy of NSW Breast Cancer Institute and Australian Institute of Health.)

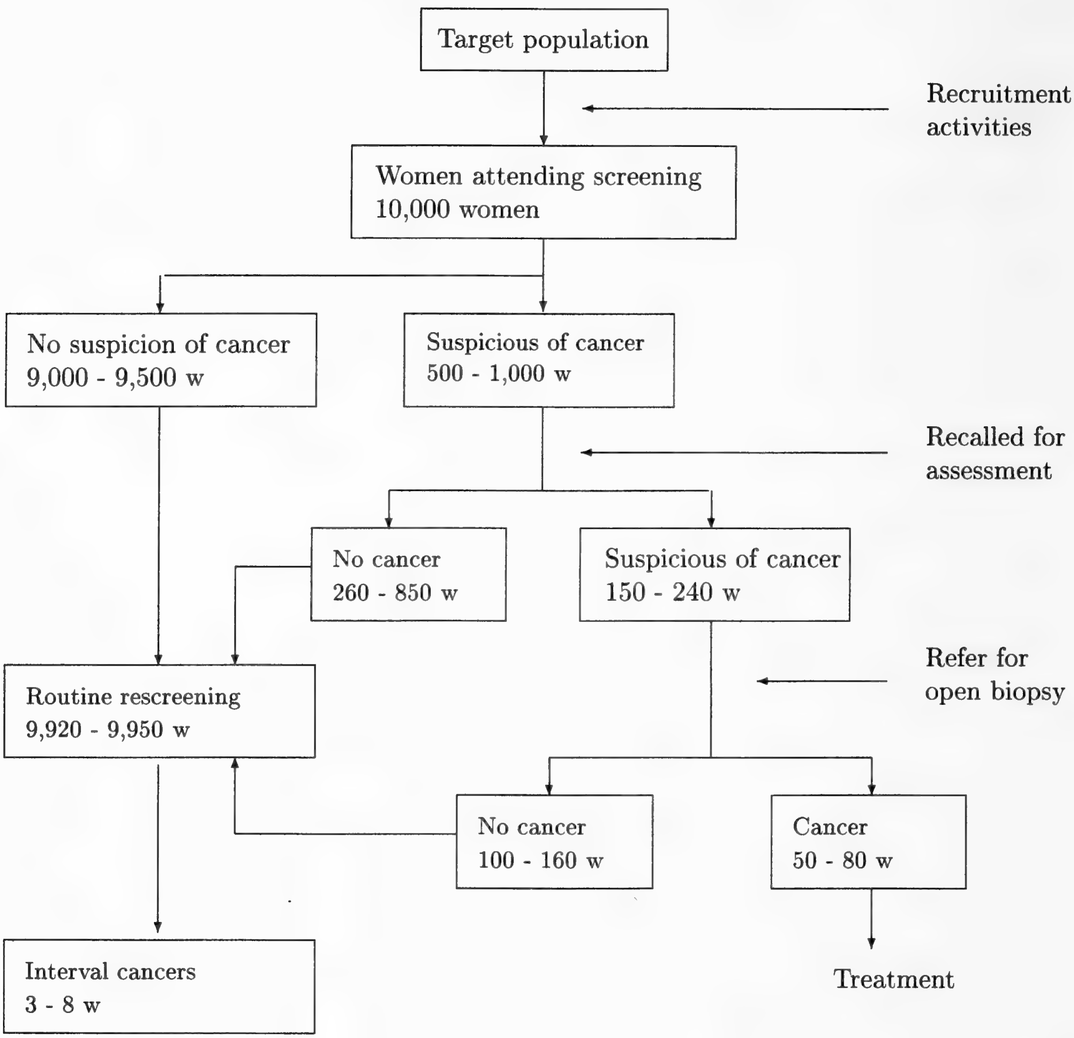

Figure 2: Initial screening - estimated number of women reaching various stages of screening for every 10,000 women screened. (Courtesy of NSW Breast Cancer Institute and Australian Institute of Health.)

PROGRESSION OF THE INITIAL INDICATION OF A BREAST MALIGNANCY

The basic cause of breast cancer is still not known but the progression is understood in terms of molecular biology. The progression may be slow or rapid and the latter situation gives rise to the problem of "interval cancers" where a tumour may develop rapidly shortly after awomen is screened as "clear" but develop to a fatal state with metastases prior to the next scheduled screening. An up to date study on this matter has recently been published (Rickard and Taylor 1998) and shows that there was no significant difference between the proportional incidence rates for the 50 to 69 year age group (for Central and East Sydney Screening) and those of major successful overseas screening trials.

The 12 month interval cancer incidence per 10,000 screens was 4.17 for the 40–49 year age group (95% confidence interval) and 4.64 for the 50–69 year age group.

TREATMENT

Surgery is the mainstay of breast cancer treatment. Fortunately a number of randomised clinical trials have shown that conservative surgical procedures result in equivalent mortality and survival rates to radical surgery (Fisher et al. 1989). Reports from some Australian sources indicate that breast conservation is possible in approximately 45% of cases (Malycha 1993).

Adjuvant therapy, particularly systemic cytotoxins or hormonal drugs such as tamoxifen, has proved effective in reducing mortality. Although the initial gains were small (Hurley 1991), more recent data is much more encouraging for reduction in mortality as summarised by McDonald and Qazi (1998).

MAMMOGRAPHY

Mammographic screening is recognised as the "gold standard" for screening for breast cancer. It uses "soft" X-rays and relies heavily on experienced radiologists' interpretations of both "direct" and "indirect" signs. However, mammogram interpretation is both time-consuming and difficult, requiring the expertise of trained radiologists. An excellent description of mammographic evaluation is given in the review paper by Sickles (1986).

Ultrasound has been shown to often augment mammography in situations such as dense breasts and cyst/solid differentiation.

Other imaging methods: ultrasound, static thermography, trans-illumination, and MRI have not demonstrated sufficient effectiveness to substitute for mammography in screening. Mammography has very good spatial resolution needed for sensitivity but is not as good in depth resolution. MRI is not very good at spatial resolution but can resolve well "layer by layer" in depth for chemical changes. It does require expert interpretation and is very costly.

MAMMOGRAPHY AS AN ACCEPTED SCREENING TEST

Specificity of Screening in the early Detection of Breast Cancer - "False Negatives" and "False Positives"

The two main concepts of diagnostic tests which are well accepted are "sensitivity" and "specificity". Those concepts are:

1. A measure of sensitivity is the probability of correct diagnosis of "positive" cases.
2. A measure of specificity is the probability of correct diagnosis of "negative" cases.

The practice of mammography has good sensitivity but is not as good in specificity. One of the main disadvantages of any screening program is lack of specificity of the screening test because a test that is not specific to the disease in question will give false positive results. A false positive result can cause the patient needless anxiety, inconvenience in having to undergo further diagnostic tests, and possible morbidity if these tests are invasive; it also results in considerable expenditure of personal and health service resources. New computer aided diagnostic methods are improving specificity as well as sensitivity (Nguyen et al. 1998).

Other epidemiological parameters derived from the basic results of mammography (see Table 1) and Rose & Barker's book (Rose and Barker 1986) on introductory epidemiology are "prevalence" and "positive predictive value", PPV.

	Reference Test (disease)		
	Positive	Negative	Totals
Survey Test			
Positive	True positives correctly identified = (a)	False negatives = (b)	Total test positives = (a+b)
Negative	False negatives = (c)	True negatives correctly identified = (d)	Total test negatives = (c+d)
Totals	Total true positives = (a+c)	Total true negatives = (b+d)	Grand Total = (a+b+c+d)

Table 1: Basic results of mammography from and Rose & Barker (1986).

From this table the following definitions are derived.

Sensitivity: A sensitive test detects a high proportion of the true cases, and this quality is measured here by a/(a + c).

Specificity: A specific test has few false positives, and this quality is measured by $d/(b+d)$.

Systematic error: For epidemiological rates it is particularly important for the test to give the right total count of cases. This is measured by the ratio of the total numbers positive to the survey and the reference tests, or $(a+b)/(a+c)$.

Positive predictive value: This is the proportion of test positives that are truly positive. Systematic error and predictive value must depend on the relative frequency of true positives and true negatives in the particular study group (ie on prevalence of abnormality).

In addition to its sensitivity and specificity, the performance of a test is measured by the predictive value of a positive or negative result. For a positive result this is given by $a/(a+b)$, which represents the likelihood of a person with a positive test having the disease. When a disease has a low prevalence the proportion of true negatives $(b+d)$ in the population in relation to true positives $(a+c)$ is greater than when prevalence is high; and the proportion of false positives (b) will be greater in relation to (a). The predictive value of a positive result must therefore fall (or rise) as prevalence declines (or increases). This point is of practical importance, because new diagnostic tests are usually first tested in hospitals or clinics, where prevalence is high. Despite satisfactory levels of sensitivity and specificity these tests may be disappointing when applied to the general population, because the yield of false positives is too great. Table 2, from Rose and Barker's book (1986), shows results from a breast cancer screening program, using palpation and mammography, where the sensitivity was 67% and the specificity 98%, yet the predictive value of a positive screening test was only 20%.

	Breast Cancer		
Screening	Present	Absent	Total
Positive	127	497	624
Negative	63	19 313	19 376
Total	190	19 810	20 000

Table 2: Results from a breast cancer screening program from Rose and Barker (1986). Sensitivity = 67% (127/190); specificity = 98% (19 313/19 810); predictive value = 20% (127/624).

Assessing a screening test requires not only a comparison with a reference test but also measurement of the test's repeatability, which shows the extent to which a single screening measurement may be taken as a sufficient guide to action. In breast screening readers are used for each mammogram and any differences in assessment referred in consultation with a third specialist.

MORTALITY VERSUS SURVIVAL RATE

In screening for cancer, the principle question is whether the identification of individuals at an earlier stage in the natural history of their disease and consequent treatment reduce mortality. It is a commonly held belief that this is necessarily the case for cancers where the survival rate varies substantially with the stage at diagnosis. However, the argument here is fallacious and can be confounding according to H. Cuckle (1990), who comments as follows:

"The first and most obvious bias is called the 'lead time' bias. Suppose that a cancer was diagnosed incidentally whilst investigating some completely unrelated problem, and the patient refused treatment. The time from diagnosis to death would necessarily be longer than had the cancer been diagnosed clinically when the patient would have presented with symptoms, yet the date of death would have been unchanged. Thus, the extra time the cancer was observed (the 'lead time') increased the survival time but did not change the outcome. The second bias is called the 'length' bias. This arises because of the variability in rate or progression of the disease, for a given site of cancer, so that for example some cancers are aggressive and will lead to death just a few years after initiation whereas other cancers of the same site are indolent and may take decades. Since the latter spend more time in the preclinical stages there are more opportunities for incidental diagnosis. It follows that in a group of cancers diagnosed early there will be a disproportionate number of indolent cases with good survival.

These biases mean that to evaluate screening for cancer the mortality rate and not the survival rate should be used, comparing it in those who are screened and similar individuals who are not."

RANDOMISED TRIALS

The randomised trial of screening is by far the most reliable source of data since it is unbiased. The cumulative breast cancer mortality rate in those allocated to the screening arm is in expectation the same as that in the control arm. Any differences that emerge will be either due to chance or to the effect of screening. The extent to which change may either cloud a true effect or lead to an apparent effect that does not exist is influenced by:

1. size of trial;
2. magnitude of the true effect;
3. compliance in the screening arm of the program;
4. screening in the control arm ('contamination') of the program;
5. duration of follow-up, and
6. method of randomisation.

As with any epidemiological study the ability to show an effect is dependent on the size of the trial and the magnitude of the true effect. The more deaths from breast cancer that accumulate the smaller the influence of chance which will be particularly important if the true effect is small. The effective size of a screening trial may be only a fraction of its actual size if compliance is low and contamination is high (Cuckle 1990, Table 1). The ability to demonstrate an effect is dependent on the duration of follow-up because the deaths prevented by screening are likely to have occurred many years after it was done. Those who die of breast cancer in the first years after screening will be predominantly women with advanced disease at the time of screening who will have derived little benefit from it. Thus the cumulative numbers of death in the two arms of the trial are likely to be small and similar in the first, say, 5 years and only begin to differ after that time.

OTHER CONFOUNDING MATTERS

Breast carcinomas are classified histologically into ductal or lobular types. Each type is further divided into in-situ and invasive categories. Ductal carcinomas in-situ (DCIS) can remain harmless for years but stellate and fast growing tumours can lead to mortality in a relatively short time if not detected (which is difficult in many cases for small tumours in a complex background of the mammographic image). This is made a more difficult task when radiologists commonly read screening mammograms at 70 to 80 an hour - often after a day's work on other matters. In the Australian screening system two views are taken (oblique and cranio caudal) but in the UK system only one view is taken and this can be a source of confounding in some cases. The increased cost of having a second reader viewing of the mammograms is considered highly desirable as explained previously.

Some non-neoplastic conditions can present clinically with a breast mass and simulate neoplasms clinically and in mammograms. Some of these are quite common lesions such as duct ectasia and fat necrosis.

TARGET GROUP FOR MAMMOGRAPHY

Meta-analysis of a number of screening studies done in the 1980's suggested that mammography has a worthwhile role in reducing breast cancer mortality particularly for women over the age of 50 (Australian Cancer Society 1993). A further meta-analysis of studies done 1966–1993 published in 1995 (Kerikowske et al. 1995) gave support to this decision. The most women who are at risk from developing breast cancer are post-menopausal women aged 50–65. In 1990 the Commonwealth Government of Australia phased in a National Program of Breast Screening biennually for women over 50 years of age and particularly those 50–69. The breast tissue of younger women is more dense than that of older women making mammography less accurate. Ultrasonography is a preferred modality for women under 30.

MAMMOGRAPHY EQUIPMENT AND RESOURCES FOR SCREENING

Mammographic screening facilities utilise soft X-ray equipment which takes oblique and cranio caudal views plus ultrasound equipment. Breast clinics are equipped with these facilities. Mobile vans with X-ray breast screening equipment are also used to cover population areas where clinics are not established. The mammograms are taken back to a major centre for processing and examination and diagnosis of suspect cases. Treatment for malignant cases after confirmation from core biopsy is usually surgical and requires only a brief bed stay for simple surgical cases. More advanced cases can require mastectomy with a longer hospital stay and chemotherapy.

COST EFFECTIVENESS CONSIDERATIONS

The differences between cost minimisation, cost-effectiveness, cost-utility and cost-benefit analysis are explained by Elliott and Harris (1997) including pitfalls in their usage. In cost-effectiveness analysis the outcome of the intervention and the comparator must be measured in the same unit such as number of lives saved.

Cost effectiveness can be expressed (Lindfors and Rosenquist 1995) as the "marginal cost per year of life saved" (MCYLS):

$\text{MCYLS} = (C_s - C_o)/(Y_s - Y_o)$ where, over the period concerned:

C_s = total cost for observation

Y_s = years of life accumulated in the screened group

Y_o = years of life accumulated in the observed group

Using this definition Lindfors and Rosenquist (1995) have calculated (in their Table 6) the marginal cost per year of life saved for a number of different screening strategies for age groups and screening frequency. The MCYLS range from $US16 000 to $US31 900.

Their most effective recommendation in 1995 was:

Age group:	50–79
Strategy:	biennial
MCYLS:	$US16 000

This strategy compares well with the Australian policy (50–69 biennially)

THE CONTINUED BASIS FOR SCREENING TESTS

Although no optimum strategy has yet been found or proven screening should be done on a continuing basis in order to detect the occurrence of breast cancer at an early enough stage to help subsequent efforts to save lives. In Australia the National Screening Program recommends testing for the target group every 2 years. The US study by Lindors and Rosenquist (1995) has suggested that for improved cost-effectiveness of breast screening women 50–79 years should be every 2 years and women 40–49 annually.

CONCLUSION

The randomised trial process is the most reliable method of assessment of efficacy of screening programs and is without bias. Many countries recommend regular screening for women of certain age groups and others in high risk groups such as those with familiar history of breast cancer. Recently the results presented from screening programs have indicated that they are effective in reducing the mortality rate (Anderson, 1998). However controversy still exists. Criticisms by Gotsche and Olsen (2000) stated that their meta-analysis of results of eight earlier trials showed that the six of those reporting favourable results had statistical randomisation faults. However the Gotsche and Olsen report is being challenged and they are also accused of omitting more recent favourable results from the two of the eight papers which reported unfavourable results. An outline of the controversy is given by Rubin (2000). Specific information continues in The Lancet correspondence pages (see Gotsche and Olsen reference entry herein).

The mortality rate from breast cancer has decreased significantly from 1995 due, in part, to the increasing utilisation of mammography (Bassett et al. 1997) and improvements in technology, film quality, double reading of mammograms, better quality control and management (Cardenosa et al. 2000). There is also the separate factor of contributions from improved treatments so the respective contributions to mortality reduction is difficult to quantify. A good summary of the practicalities and problems, including human aspects, associated with screening programs as well as the benefits has been given by Hirst and Kearsley (1991) with particular relevance to Australia's first population based mammography screening project as well as four international screening studies at that time. They clearly pointed out that "mammographic screening is not simply a technical exercise". Quality control, strategic organisation and experienced staff are necessary for success and is now evidenced in reports such as the year 2001 Report on Government Services, section on Breast Cancer. Also since 1994 in the USA the Mammography Standards Act required Federal accreditation of all mammography facilities.

The evidence available to date suggests that, provided there are optimal conditions of quality control and staff expertise, mammography has the potential to reduce mortality from breast cancer. Screening is often multidisciplinary and a successful effective program may mean cutting across normal professional and organisational boundaries.

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Geodiversity Symposium, Australian Museum

F.L. SUTHERLAND, CONVENOR

The following abstracts are associated with a special Geodiversity Symposium organised by the Geodiversity Research Centre at the Australian Museum to mark the retirement of Dr F.L. Sutherland from his Museum position. The Symposium was opened by Professor Evan Leitch, President of the Geological Society of Australia.

The abstracts cover the fields of research conducted by the Australian Museum during the tenure of Dr Sutherland in the past three decades and involved co-workers from the Museum and other institutions, both Australian and overseas.

The convenor hopes that by publishing these abstracts of the Symposium The Royal Society of NSW will be promoting the wide diversity of geological topics presented at the Symposium.

Communicated by Dr F.L. Sutherland
All abstracts received: 8.01.2002

Garnets, Diamonds; Diatremes and Subduction, Bingara Area, NSW

B.J. BARRON, L.M. BARRON & G. DUNCAN

At Bingara-Copeton, NSW Australia, alluvial diamond deposits are Cainozoic "headless" placers in the Phanerozoic New England Orogen, more than 1500 km distant from the nearest craton. The diamonds possess a unique rounded morphology with twin planes or naats, unusual metamorphic calc-silicate-eclogitic, and mafic-eclogitic inclusions. Age dates on diamond inclusions are Late Palaeozoic-Early Mesozoic (340 ± 28 Ma, 326 Ma, Carboniferous; and 218 ± 6 Ma, Triassic); but interpretation of these dates is controversial.

Some workers suggest diamond formation during subduction, either through direct crystallisation within a downgoing slab or through an indirect subduction related mechanism. Certainly the New England region has a complex Phanerozoic tectonic history of subduction-accretion and tectonic underplating. Others suggest diamond formation in cratons prior to Gondwana breakup, and then surface transport for thousands of kilometers. However, it is unlikely that so many diamonds with such unique features would locally concentrate in a placer deposit, except from a proximal source. To find a hard rock diamond source, exploration elsewhere is focused on cratonic diamonds and peridotitic "indicator" assemblages. Most sought is sub-calcic Cr-rich (G10) garnet (depleted garnet harzburgite mantle source), together with high Cr chromite, and Mg-rich ilmenite.

Heavy mineral concentrates at Bingara are "flooded" by disaggregated spinel lherzolite minerals from xenoliths in Cainozoic basalts, masking some conventional peridotitic "indicator" minerals such as chromite, ortho- and clinopyroxenes. However, diamonds at Copeton-Bingara are predominantly eclogitic and would not come from peridotitic host rocks. Therefore high sodium eclogitic garnets should be prime exploration targets.

Unlike the Cainozoic placer deposits, the authors report that the modern drainage at Bingara contains abundant eclogitic garnet and minor sapphirine, staurolite and kyanite indicating derivation from a high to ultra high pressure (HP to UHP) metamorphic source. The country rocks are low grade Devonian metasediments that lack such mineralogy. Therefore the HP minerals are shedding from xenoliths in local post subduction alkaline intrusives and diatremes, or from obducted blocks (mainly along the 1200 km long Peel-Yarrol Fault zone).

Analysed Bingara garnets are almandine-pyrope compositions, with lesser iron-rich almandine-spessartine, minor low-Cr pyrope and rare grossular and andradite. Based on recent chemical models most plot in the fields for eclogite or megacryst suite garnets, but three diamond eclogitic garnet groups are defined in the tenement areas of Rimfire Pacific Mining NL. One is on twin hills called Tom and Jerry where a recent bulk sample returned a 0.265 ct diamond. Rare earth element (REE) analysis of 24 selected garnets show three distinct patterns mainly in the heavy REE (HREE). Pattern I belongs to HREE, Fe- and Mn- enriched (almandine-spessartine) garnet. Similar garnet is found in feldspathic fractionated orthogneissic rocks of ultrahigh pressure terrains such as Dabie Shan China. Patterns II and III in megacryst, eclogitic and diamond eclogitic garnets reflect metamorphosed unfractionated Mid Ocean Ridge Basalt and arc basalt protolith respectively. The garnet chemistry and REE patterns indicate at depth an extensive eclogitic- to locally diamond eclogitic-grade metamorphic terrain with a variety of protoliths. This strongly supports a local UHP metamorphic origin for the eclogitic diamonds that belong within the Bingara-Copeton tectonic setting; they are unlikely to have been transported far.

Hornsby Diatreme: Mechanism for Formation.

L.M. BARRON

The Hornsby quarry is no longer worked as a quarry but has potential for storing clean fill, for becoming a heritage site and as a study site for diatremes.

A diatreme passes up through an unbedded throat (up to several kilometres in depth) into an upper bedded facies (the upper ~1000 m). This is topped by a low volcanic cone ridge (~30 m) around the depressed centre, with a thinly bedded apron extending several kilometres away from the centre. In the dormant or extinct stage, a lake (maar) occupies the central depression. The mechanism for formation of the upper diatreme facies typically shows subdued dips and topography, as this occurs at many well preserved diatremes e.g. Atherton Tableland (Queensland). Conversely, steeply bedded base surge rocks are presumed to have formed initially with low dips, then collapsed to their present attitude. Diatremes result when rising magma hits a water table or zone of rapid depressurisation. The explosive energy shatters the hot magma and vent walls into angular fragments of palagonite, crystals, country rock and surface materials. The diatreme forms in cycles, beginning with an extreme blast followed by an infill series of fall back and base surges. Through these cycles, the diatreme structure burrows downwards growing like a tap root and may reach 7 km depth. When the diatreme structure is open to the surface, a negative pressure allows more magma to rise explosively from depths in the mantle, carrying up mantle and crustal material. Many diatremes have been mined for diamonds, entrained from depths of 250–400 km.

Over a twenty year period, quarrying at Hornsby has revealed "classic" shallow dipping base surge beds in the east wall. Conversely, a puzzling feature emerged with steep inward dipping base surge beds on the other walls. In December 2000 all walls of the quarry were examined and photographed. These photographs suggest a modified mechanism formed the upper bedded part of this diatreme. The Hornsby quarry shows two centres of eruption. One formed the shallow dipping east wall with a centre east of the quarry (outward dips). A second, inside the quarry, shows inward dips on the north, west and south walls. The latter centre has steep dip slopes for over 100 m in all directions, which are coherent for > 75% of the quarry. A volume of about two years of extraction was left behind in the quarry walls because the coherent steep inward dip caused problems in mining. If this bedding had formed with shallow dips and subsided to its present steep geometry, it would show many 'orange peel' tears. Their absence indicates a steep original bedding disposition. Thus > 80% of the Hornsby diatreme is incompatible with published models of diatreme formation.

A modified mechanism, compatible with both the shallow and the steep dipping portions, involves a startup explosion strong enough to create a large open cavity which becomes the focus for a new eruption centre. Medium and smaller eruptions then fill in the cavity with base surge deposits. The base surge eruption cloud is generated at the bottom of the infilling cavity, and travels outwards as a thixotropic pyroclastic flow. This donut shaped flow has a rolling front of water/steam fluidised mass of crystal and rock fragments and minor to dominant mud. It may be hot enough to convert pieces of broken trees to charcoal (340°C). Although the front may travel at 150 kph, the rolling nature of the front means there is zero velocity at the bottom of the flow. Thus the base surge layer attaches to the surface of propagation as a centimetres to metres thick layer in one pass, and due to the thixotropic character, hardens instantly. This is why base surge deposits take on the dip angle of the cavity, regardless if shallow or steep. Base surge deposits have been reported as adhering to vertical, and downward facing surfaces (e.g. on light houses damaged by base surges on volcanic islands). Hornsby quarry is a superb example of this mechanism.

Serendipity in the Discovery of New Australian Minerals

BILL BIRCH

All new mineral discoveries require a degree of luck or, as the author prefers to call it, serendipity. Curiosity is another essential element. As the characterisation of a new mineral takes at least three years between discovery and published description, patience is another virtue in this field.

Among 24 new species the author has co-described so far, 21 have either Australian type localities or occurrences in Australia (see Sutherland et al. 2000). All but one are secondary minerals, often with quite complex chemistry, especially the zirconium phosphates and bleasdaleite. Most were forwarded for investigation by mineral collectors. About 5 or 6 were already in the Museum's collections when research was started on them (for example, perroudite, baumhauerite-2a, bernalite and bamfordite).

Each new mineral has its own needs for establishing the species and most are not straight forward descriptions. The work involved colleagues to help characterise them and some were approved without any problems (for example, sieleckiite, ulrichite and mawbyite).

In a few cases, other mineralogists were working on a particular new species at the same time. These could be considered to be hard luck cases, as Australia missed out on establishing an Australian type locality. However, the international mineralogical grapevine often works surprisingly well, so that the first description of a new species, Australian type locality or not, can often cover all known occurrences at the time (for example, perroudite and meurigite). In a few more cases there were near-misses, whereby a new species from elsewhere was approved only a few months in advance of a proposal for the same species from Australia being submitted to the International Mineralogical Association Commission on New Minerals (for example, hentschelite). There were other discoveries of rare species where the type specimens were described only a few years previously (for example, kosnarite and mrazekite).

Serendipity has played a bigger than normal role in the discovery of some species, perhaps because they were lucky to survive at all, either in a quarry face (for example, wycheproofite) or in an old collection (for example, bernalite).

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Precious-Opal-Filled Vesicular Basalt ("Leopard Opal") From Zimapan, Hidalgo State, Mexico.

ROBERT RAYMOND COENRAADS & ALFONSO ROSAS ZENIL

The Leopard Opal deposit is located 14 kilometers to the southwest of the town of Zimapan in Hidalgo State, Mexico at latitude 20°42´N, longitude 99°28´W (grid reference 452E 2288N on the Tecozautla topographic map sheet).

The right combination of several favorable factors have led to the formation of precious opal in empty gas cavities in a vesicular basalt overlain by volcanic ash of Tertiary-Quaternary age. These factors include:

1. *Availability of Silica*: It is reasonable to assume that the silica-bearing solutions responsible for the deposition of the opal in the vesicles and fractures within the basalt flows originated from the immediately overlying tuffs and breccias. Exploratory mining carried out by one of the authors, Alfonso Rosas, found that the concentration of opal in vesicles and along fractures is highest in those immediately adjacent to the geologic contact, falling off rapidly within a distance of five meters.

2. *Permeability of the vesicular basalt and porosity of the right shape and size*: Permeablity is essential for the silica-bearing solutions to be able to penetrate the basalt and reach most of the open spaces. The shape and size of the vesicles are also important; the abundant, but small sized vesicles, and their uniform distribution, being necessary for an appealing product. If the vesicles were larger, filling would have been most likely incomplete leaving the silica as a thin skin lining the inside of the cavity wall. The larger accumulations of crystal opal and fire opal that have formed in cracks in the basalt may also be of interest but, like opal found in other volcanic environments, they may display a tendency to be fractured.

3. *Environmental factors that favor the formation of opal instead of cryptocrystalline silica, and also those favoring precious opal formation over common opal*: These factors are still-as-yet unknown, apart from the fact that the silica-bearing waters would have had to be introduced over a period of time and at relatively low temperatures. Also, due to the instability of the precious opaline silica, we can assume that the deposit has not been subject to a significant heating event which would have led to recrystallization of the precious opal into a more-common crypocrystalline silica product.

The deposit has only been slightly explored to date by a number of small test pits and significant potential remains for its further development.

A market evaluation of the leopard opal was carried out at the Tuscon Fair in February 1996.

At the Fair, US$1,500 worth of material was sold quicky at prices between US$8 and $20 per carat.

A New Species of the Enigmatic Mammal Genus Tingamarra: a Placental Mammal in the Court of King Kangaroo?

A. GODTHELP, M. ARCHER, S.HAND & K. ALPIN

In 1992 Godthelp, Archer, Chiffelli, Hand and Gilkeson described the fossil mammal *Tingamarra porterorum* from among a diverse assemblage of vertebrates found in 55 mya sediments in Southeast Queensland. On the basis of cusp morphology and enamel ultra-structure we assigned *T. porterorum* as a placental mammal. Some authors (Woodburne and Case, 1996) preferring a relationship to the Prodidelphidae such as the "Itaborain" aged *Bobbschaeferia flumensis* have challenged this determination. Recently a tooth representing a second much larger species in the genus Tingamarra has been identified from the Tingamarra Local Fauna. This and the discovery of an unequivocal terrestrial placental mammal periotic have encouraged us to review the evidence and revisit some aspects of the geology and age of the deposit.

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Sapphires, Zircons and SHRIMP: the Sutherland Connection

C. MARK FANNING

Zircons and SHRIMP (Sensitive High Resolution Iron Micro-Probe) U-Pb age determinations form a minor but important tangent to the Geodiverse Sutherland. Zircons occur as inclusions in corundums (sapphires) within basalts and as megacrysts in basalt fields. Such zircons may be seen to have three general parageneses. There are syngenetic zircons that provide valuable estimates of the crystallisation age for the enclosing sapphire. Some inclusions and megacrysts are structured, with older inherited components overgrown by magmatic rims.

Yet others are considered to have had a disruptive growth in their paragenesis. The Sutherland approach has been to link SHRIMP ion microprobe U-Pb ages taken in situ within such zircons and connect them to the geological history. The recognition of the various zircon modes, and the ages determined has had a significant impact in the understanding of the formation processes for gem corundums.

(*ed. See Figures 1 and 2 overpage.*)

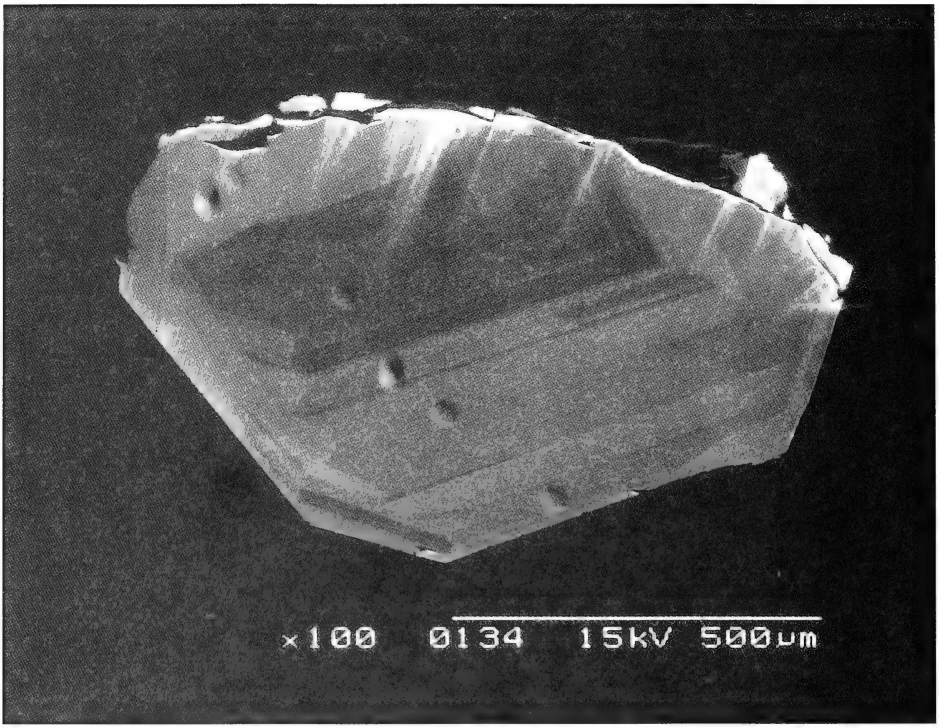

Figure 1: Syngenetic zircon showing growth bands in saphire.

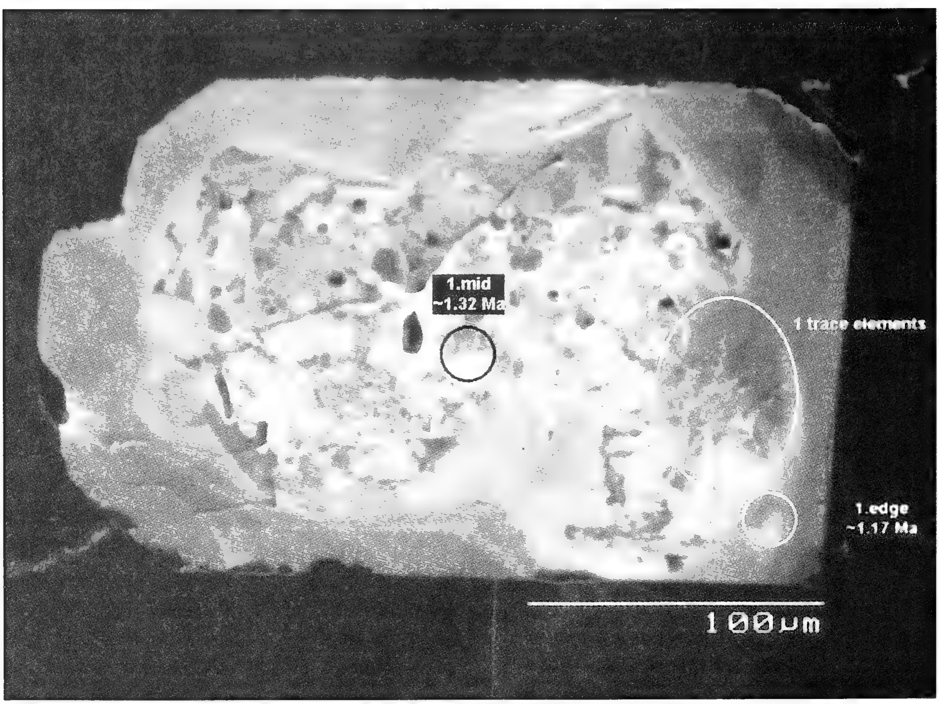

Figure 2: Older corroded xircon overgrown by magmatic zircon rims.

Geodiversifying in South Africa: the Bushveld - Karoo Story and More

I.T. GRAHAM, S.A. DE WAAL, R.A. ARMSTRONG, D. PHILLIPS & W.D. MAIER

South Africa is smaller than Australia though just as geologically diverse and contains an unparalleled geological record of the earth's major crust-forming events from the 3640 Ma Ancient Gneiss Complex and Barberton Greenstone Belt up to the present-day. The Transvaal Basin covers a large part of the Kaapvaal Craton and consists of 15 km of relatively unmetamorphosed clastic, chemical sedimentary and volcanic rocks. Although the volcano-sedimentary Rooiberg Group was included within the Transvaal Supergroup in the past, recent work has shown that it is the early extrusive manifestation of the 2055 Ma Bushveld magmatic event. The Transvaal Supergroup now consists of three main successions, the lowermost Black Reef, central Chuniespoort Group and an upper Pretoria Group. A U-Pb zircon evaporation age of 2549.9 $\pm$ 2.6 Ma was obtained by Walraven & Martini (1995) from near the base of the Chuniespoort Group and a Rb-Sr whole-rock age of 2224 $\pm$ 21 Ma was obtained by Burger & Coertze (1973) from the Hekpoort andesites of the lower Petoria Group. In this study, we obtained hundreds of detrital zircons from near the top of the Pretoria Group within the Stavoren fragment and have come-up with an approximate age of 2100 Ma (work is still continuing to better constrain this age). As this age is based on detrital zircons, it represents a maximum age for the top of the Transvaal Basin.

The Bushveld Complex is the world's best-known layered mafic-ultramafic intrusion due to its fantastic exposure, uniformity of layers, and enormous deposits of the platinum group elements, chromium and magnetite. It has intruded into the Transvaal Supergroup and was previously considered to consist of 6 main parts. However, recent work (Harmer pers. comm 2001) has shown that it is much larger and includes an early eruptive felsic volcanic phase (Rooiberg Group; 2057 Ma), granophyre phase (Rashoop Granophyre Suite; 2062 Ma), intrusive granite phase (Lebowa Granite Suite; 2054–2057 Ma) and layered complex (Rustenburg Layered Suite; 2055 Ma). Thus, the entire sequence of over a billion cubic kilometres of magmatic rocks formed within the narrow time range of 5 Ma.

The present study has focused on the dioritic, granitic and volcanic sills that occur stratigraphically below the Bushveld Complex, termed the sub-Rustenburg Layered Suite dioritic sills. The Marble Hall diorite consists of more than 30 individual sills that extend from the surface down to at least 506 m. Geochemically, the diorite is similar to dioritic and gabbroic rocks of the Bushveld Complex and chill zone gabbros of the Uitkomst Complex. De Waal & Armstrong (2001) obtained a U-Pb zircon SHRIMP age of 2055.6 $\pm$ 3.1 Ma, that is, coeval with the Bushveld Complex. In places, a well-developed autobreccia is associated with this diorite and consists of angular to subrounded fragments of diorite, meta-dolomite and chert in a breccia fill of mainly ferroan pargasitic hornblende. Field evidence suggests that this brecciation event was the last pre-Karoo age magmatic event within the Marble Hall Fragment. Due to the lack of zircons within the breccia-fill, the Ar-Ar method was used on hornblende grains. The age obtained of 2062 Ma suggests that this brecciation event formed an integral part of the main diorite emplacement. Understanding the geological history of the Vredefort Dome region is vitally important as it contains the Witwatersrand Basin (containing some 50% of the world's gold resources). Three main intrusions were dated within this region, the Schurwedraai (2044 Ma), Roodekraal (2054 Ma) and Lindequestdrift (2053 Ma U-Pb; 2051 Ma

Ar-Ar). The Schurwedraai granite is thus slightly younger than the main Bushveld magmatic event but the other intrusions are comparable. This is highly significant as many authors in the past have postulated a Bushveld age for the metamorphism and gold mineralisation within the region but failed to find any evidence of intrusive rocks of this age. It also shows that the Bushveld magmatic event was much larger than previously postulated and so the larger-scale tectono-magmatic models for the development of this event and metamorphism/gold formation within the Witwatersrand Basin will have to be re-examined.

The Karoo Province covers a vast area of Southern Africa. Though largely dominated by sedimentary rocks and basaltic lavas, it also contains a number of intrusive bodies. The Insizwa Complex is one of the largest of these intrusions and comprises 5 distinct Iobes (Insizwa, Ingeli, Tabankulu, Tonti and Horseshoe). These sills generally have a basal picrite overlain by gabbro. Our aim is to study the mineralogy and composition of calcareous xenoliths that occur within the only massive nickel-copper sulfide (PGE) deposit of the region, the Waterfall George Deposit, and determine the significance of these with respect to the genesis of the mineralisation which occurs at the contact between the basal gabbro and underlying metasedimentary rocks.

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Distribution And Origins Of Heavy Minerals In The Post-Palaeozoic Alkaline Volcanics Of West-Central Victoria, Australia

JULIAN D. HOLLIS

Volcanism has occurred across southeastern Australia over the past 200 Ma, with few prolonged intermissions; although activity was regionally restricted for much of the time. Eruptions in west-central Victoria were concentrated mainly during four intervals, based on available dating. There are broadly distinctive heavy mineral suites characterising volcanics of each interval.

Interval 1, from ~195 to ~145 Ma, the Jurassic Volcanics, was apparently in response to pre-Gondwana breakup tension. This saw the widespread eruption of mainly primitive magmas, including kimberlites, in parts of South Australia and Victoria. Sources are now preserved only as pipes and dykes. Heavy minerals are frequently high-pressure magmatic and mantle components, notably Cr-Mg rich garnets, diopsides, spinels, and Mg-ilmenite. Kimberlite-related pipes with distinctive minerals are concentrated in a northerly belt from Lethbridge and Huntly, along which there are unconfirmed reports of diamonds. There are also phlogopite-rich lamprophyre dykes.

Interval 2, from ~85 to ~50 & and possible minor 38 Ma, here called the Ballan Volcanics, coincided with plate separation; Australasia breaking from Antarctica. Voluminous alkali volcanism occurred across western Victoria. Extensive magma fractionation systems yielded major syenitic-gabbroic differentiates, rich in zircon, corundum and Al-spinel. Pyroclastics and flows have been protected from erosion in parts of the Ballan Graben and beneath Newer Volcanics westwards. Uplift and erosion of the West-Central Highlands after 45 Ma caused the removal of the Ballan Volcanics, exposing dyke swarms. In mafic dykes there is an inverse abundance of magnesiochromite to zircon-corundum.

Interval 3, from ~25 to ~17 & and possible minor 11 Ma, here called the Mid-Cainozoic Volcancis, produced scattered alkali basalts and tholeiites with late zircon-bearing differentiates.

Interval 4, the Newer Volcanics started ~8.5 Ma and is still current. The province shows one of the densest late Miocene to Recent vent desities known, with over 700 eruption centres. Diverse deeper crust-mantle xenolith suites are most widespread in the Newer Volcanics: They include many composites, from which deeper terranes can be modelled. Most volcanic systems have few xenoliths, but weathering has released abundant refractory minerals. Many can be directly related to those analysed from xenoliths. Cognate heavy minerals, in particular zircon, give information on crust-mantle magma fractionation histories.

A total of 426 Newer Volcanic eruption centres have been located over 8000 sq. km in West-Central Victoria, west from the Melbourne-Seymour corridor. Refractory heavy mineral distribution is recorded from regolith samples taken directly from volcanic centres and from adjacent alluvials at some 1200 localities. Residual heavy mineral occurrence from eruption centres in the highlands region recorded 96% with zircon, 29% with corundum, 29% with garnet and 8% with apatite. The dense distribution of vents enables the analysis of probable linear and curvilinear structural controls. Ovoid, volcano-free areas of country rocks, bordered by patterns and heavy mineral distribution shows several anomalous patterns; Corundum exhibits strongly localised type distributions that define deep petrographic belts. These show little relationship to major surface formations such as the Heathcote Axis. Anomalies include a Macedon-Mornington Belt of metamorphic platy corundum; a blue "syenitic" corundum zone from west of Meredith to near Kyneton and a west-northwestern fracture with pink-purple corundum near Daylesford. A distinctive kaersutite-apatite-mica suite in mantle-fractionated basalts from Anakie E. Hill and from Brimbank, near Blampied may represent Na-rich equivalent of the MARID Suite and is here called the *Amphamic Suite.* Hydrous P-rich fluids of the suite produced amphamic metasomatism of crust-mantle cumulate pyroxenites. Another peculiar suite shows a dark red garnet-enstatite-ulvospinel-ruby corundum association; here termed the *Enpyraltic Suite.* This occurs in association with eight volaticlastic systems that are largely obscured by later eruptives. These are only detectable from heavy minerals.

Alkali-type zircon is widespread each of a line from Lexton to Meredith. Most came from syenitic magma differentiates, represented by a xenolith of zircon syenite from basalt near Daylesford. Zircon also occurs in gabbroic xenoliths at Anakie E. Hill and Stewart Hill, Ullina. These xenoliths may be of Cambro-Ordovician age. Prolific cognate zircon suites come from trachytes in the Macedon and Trentham areas. Nine distinct suites of heavy minerals are defined from the Newer Volcanics.

Gloucester Ruby Project - An Update

PETER KENNEWELL

Without the input of Australian Museum staff Oliver Chalmers and Lin Sutherland, Cluff Resources Pacific NL may not have had a ruby project. Folklore has it that a keen prospector and backhoe operator for Gloucester Council, Archie Chubb, discovered red gems while prospecting for gold during his lunchtimes in Barrington Tops. After coming to Sydney and being told that rubies did not exist in Australia, he rather dejectedly called into the Australian Museum to look at their mineral display. There the stones were recognised, and a research program spanning several decades was commenced.

Rubies occur in several swamps throughout the Barrington Tops, and the Gummi River Flats, which drain some of these swamps. They were investigated by pitting during the 1970's. These alluvial deposits were not developed, as inexpensive Asian cutting was not available at the time. Cluff, in collaboration with the landowner, a Company within the Packer Group, is at present completing the investigation. This has resulted in an inferred resource of twelve million carats of rough ruby and pink sapphire, with the lower parts of the river flats still to be investigated. Small sapphires are also present.

Ruby bearing gravels have been mapped and evaluated by eleven large trenches, up to five metres deep and two hundred metres long, and processed though a 150 tonne per day trommel and jig plant. Plant concentrate, carrying rubies, was upgraded by further jig treatment, and was magnetically separated to remove spinel and ilmenite in the Company's Sydney workshop. The rubies are then hand picked. Heat treatment of the stones may also be carried out in the Company's workshop, moving the colours towards either an orange or a purple tint. The Company has established a cutting factory in Bangkok which is producing about five thousand cut carats of ruby and sapphire per month. Classification by size, quality and colour is then completed in either Bangkok or Sydney.

The stones occur in three separate gravels, which are present beneath different river terraces. Each gravel has different characteristics, and carries different suites of ruby. The Upper Terrace has poorly sorted gravels which are weathered or altered, and contain smaller stones, paler and with fluid inclusions. The Middle Terrace has larger stones of bright colour, and lower grades. The Recent Alluvials contain the bulk of the inferred resource, and have high grades and mixed qualities of stone.

It is speculated that the area's large swamps are remnants of maar (gas volcano) lakes which became quiet a short time ago, geologically speaking. Middle Terrace gravels carry good ruby in the upper reaches below Boggy Swamp, and loose grade downstream, suggesting that the swamp was a ruby source during gravel deposition.

Similar aged gravels are almost barren below Backwater Creek Swamp, but Recent Alluvials in the same valley and carrying grades up to 19 carats of ruby per tonne. This demonstrates that either an outcrop of ruby bearing rock was recently exposed and eroded, or that this swamp is the lake of a ruby bearing maar which erupted after deposition of the barren Middle Terrace. The latter theory is supported by the regional occurrence of ruby in swamps, and, if correct, would demonstrate ruby bearing volcanic gas activity immediately preceding the Pleistocene deposition of the Recent Alluvials. It is consistent with geologically young zircon dates obtained by the Australian Museum in the district.

Minerals of Jenolan Caves - Geosphere Meets Biosphere

R.E. POGSON, R.A.L. OSBORNE & D.M. COLCHESTER

Jenolan Caves, discovered in 1838, is one of the premier tourist attractions of NSW, located 182 Km west of Sydney, in the main Dividing Range. The caves are developed in the N and S sides of a natural bridge (The Grand Archway) in folded, near vertical late Silurian limestone.

Interactions between the geosphere and biosphere have formed a range of mineral species, some not previously reported from Jenolan. One suite has resulted from mainly geological processes - illite, kaolinite, goethite, hematite, aragonite, hydromagnesite, huntite, dolomite, montmorillonite, and gypsum; while another has been formed from interactions between geological and biological processes, through the activities of bats and wallabies - ardealite, gypsum, hydroxylapatite, taranakite, crandallite, montgomeryite, niter and sylvite (Colchester et al., 2001). Some caves have remnants of a later ferroan dolomite palaeokarst infill (Carboniferous to Permian age?) containing minor oxidised pyrite (Osborne, 1999).

This study has produced the most significant advances in Jenolan mineral studies since the work of Mingaye (1899), providing data on the formational processes of the cave system. The study used a variety of analytical methods - X-ray diffraction, ultra-violet photography, EDS analysis, fluid inclusion thermometry, XRF, sulfur isotope studies and K-Ar clay dating.

Two important aspects of the study have included a detailed geodiversity survey of Ribbon Cave, and relocation of Mingaye's mineral sites for application of modern analytical methods. The Ribbon Cave survey revealed for the first time the presence of huntite growing from the ends of aragonite helictites and spheres of acicular aragonite ("stars") in weathered wall rock.

Research published so far (Colchester et al. 2001) focused on an evaporite deposit in the Grand Archway in which niter occurs in association with sylvite, but not halite. This is attributed to evaporation taking place close to freezing temperatures during the winter.

Sulfur isotope studies of Jenolan gypsum and ardealite gave two separate groupings, interpreted as sulphur from (i) decay of pyrite in ferroan dolomite palaeokarst (low values, δ^{34}S 1.4 – 4.9) for one gypsum suite; and from (ii) biological (possibly bat guano) origins (high values δ^{34}S 11.4 – 12.9) for ardealite and associated gypsum.

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Silica Phases of New Zealand Sinters

K.A. RODGERS

Silica sinters are remarkable, persistent, terrestrial, surface sedimentary deposits formed from near-neutral alkali chloride hot springs, derived from deep reservoirs hotter than 175°C. They provide indications of exploitable geothermal reservoirs and associated epithermal deposits, as well as furnishing invaluable information about climate change, mineral-microbe associations in hydrothermal systems, life in extreme environments, and ancient environmental gradients.

The Auckland Sinter Programme has demonstrated that when first formed, silica sinter consists of opal-A, a non-crystalline silica phase. It forms principally as microspheres, typically 4–8 μm in diameter. Flocculation of polymerised silica from the near neutral spring waters, is facilitated by abundant cations, with microbes and other organisms affording a biochemical substrate on which the silica particles accumulate. Distinctive textural moulds reflect the biological templates about which the silica was deposited.

Sinter deposits mature, both in their mineralogy and texture, with little or no burial. With time alone, the FWHM (full width at half maximum) of the characteristic opal-A x-ray scattering broadband at ~4 Å slowly decreases by 2° 2θ over 10^4 years. This can be traced from the moment of deposition and indicates a steady reduction in disorder of the opal structure. Subsequently, opal-A crystallises to paracrystalline opal-CT ± opal-C that forms distinctive lepispheres, < 10 μm in diameter, of thin bladed crystals (*ed. See Figure 1 overpage.*). This microtextural change is accompanied by an abrupt reduction in FWHM of the ~4 Å scattering band, from 6–8° 2θ (1.6–1.25 Å) in opal-A, to 0.5–1° 2θ (0.16–0.06 Å) in the ill-defined diffraction lines of opal-CT. Subsequently, recrystallisation to microcrystalline quartz ± moganite occurs with quartz developing in clusters of euhedral, doubly-terminated microcrystals, < 5 μm long.

The complete mineralogical transformation takes 30–40,000 years, unless assisted by heat or other minerals. During this period particle densities increase, while the water content and porosity of the sinter mass decrease. The textural changes that accompany the phase changes follow diverse paths. In some instances the original biological templates are pseudomorphed. In others they are obliterated.

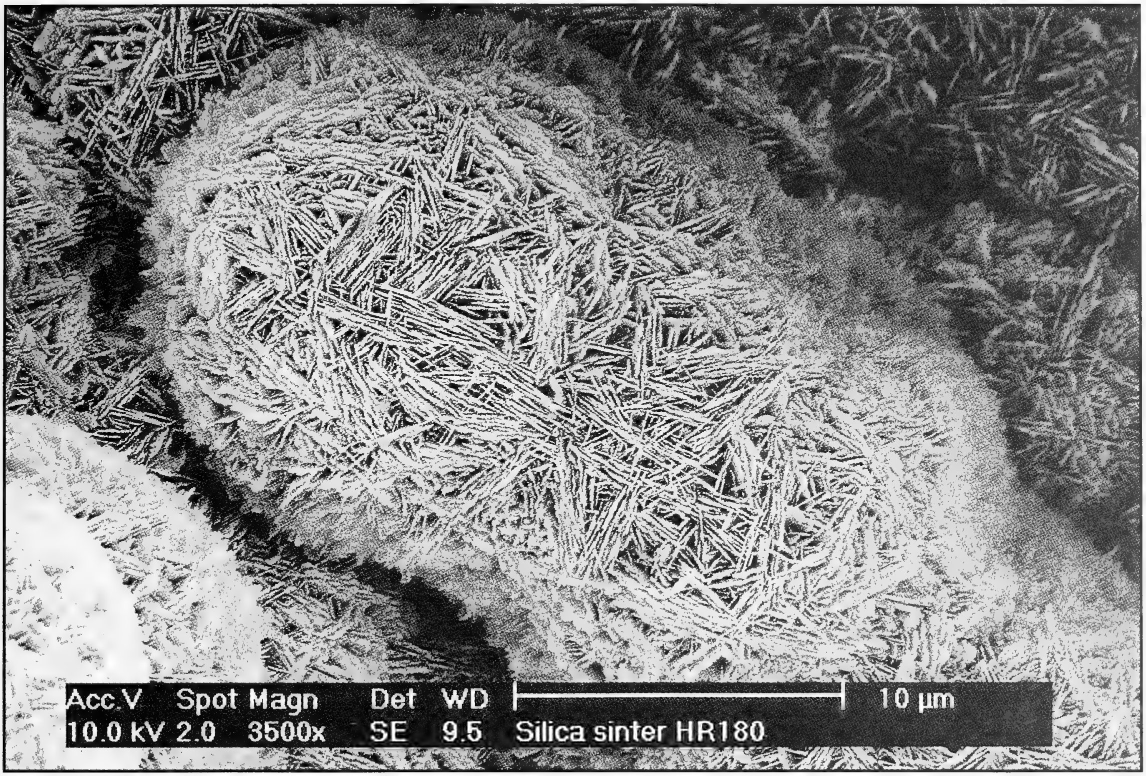

Figure 1: Opal-CT lepispheres - Otamakokore sinter.

Volcanic Impacts on Prehistoric Human Settlement in West New Britain, PNG

ROBIN TORRENCE

Inter-disciplinary research involving geology, archaeology, geomorphology, physics, and biology is beginning to reveal a fascinating story of human persistence in the face of repeated catastrophes caused by volcanic eruptions, earthquakes, and tsunamis. The setting is the western part of New Britain Island, Papua Nuigini and particularly the region near Talasea which is famous for obsidian flows used extensively in the past for cutting tools. Obsidian from this region was transported to New Ireland circa. 20,000 bp, representing the earliest long distance maritime trade in the world. At around 2–3,000 bp obsidian trade networks were the largest ever known in prehistory.

Following the exploratory work of Lin Sutherland, Julian Hollis and Jim Specht in the early 1970s, Machida et al. (1996) reconstructed the history of the Witori and Dakataua volcanoes and plotted the spatial distribution of their thick airfall - tephras which repeatedly buried and effectively sealed whole landscapes throughout the Holocene. Although undoubtedly these events created human disasters, they are a great benefit for archaeology because the tephra layers provide a chronostratigraphy that forms the basis for relative dating of archaeological sites across a vast area.

Archaeological research utilising the tephra stratigraphy has revealed punctuated history of human settlement characterised by prolonged abandonment in the wake of most, but not all eruptions, followed by reoccupation. The relationship between length of abandonment and severity of a volcanic event, however, is not straightforward since different social mechanisms, including trade, were able to mediate the effects of loss of land to differing degrees. Changes in the use of obsidian sources can also be detected since the Dakataua and Witori volcanoes impacted on different regions.

The most recent work has extended the story back into the Pleistocene with the finding of a remarkable series of heavily weathered tephras interbedded with soils containing obsidian artifacts and ovenstones. This site demonstrates that people have been coping successfully with a highly active volcanic environment since they first colonised New Britain at least 35,000 years ago.

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Growth of the Australian Museum Gemstone Collection

GAYLE WEBB

The Australian Museum mineral collection contains around 53,000 specimens, of which some 600 are gemstones. Although a small part of the overall collection, the gemstones have always created great public interest. They have featured in the Mineral Gallery for many years and, currently, this is the only Australian museum with a comprehensive and sizeable gemstone exhibit. Successive curators have been active in building up the gem collection. In 1887, Felix Ratte, the Museum's first curatorial mineralogist, started the first Mineral Register and, during the 1890s, many gemstones entered the collection, as the Museum became a repository of the state's mineral wealth. In 1901 Charles Anderson became Curator of Minerals and, during his curatorship, the Museum purchased two fine collections of mainly NSW minerals: from D.A. Porter and George Smith. These contained faceted topaz, quartz, beryl and garnet from New England and the Oban River, NSW. Curatorship of the mineral collection passed to Thomas Hodge-Smith in 1921 and further collections were purchased from George Smith and D.A. Porter, containing cut quartz, topaz, sapphire, opal, zircon and garnet. In 1929 Oliver Chalmers joined the Museum as a cadet under Hodge-Smith, becoming Curator in his turn when Hodge-Smith died in 1945. Oliver was an active supporter of gemstones. He was one of the original founders of the Gemmological Association of Australia and taught gemmology students for many years. His ties with the gemstone world extended to the gem trade, gem miners and fossickers and international gemmologists. Oliver's book, *Australian Rocks, Minerals and Gemstones*, published in 1967, was a uniquely comprehensive account of Australian localities, in print for many years. Before retiring in 1971, Oliver recruited Lin Sutherland, then Curator of Minerals at the Tasmanian Museum and Art Gallery in Hobart, to take his place. Lin was a geologist with a strong interest in gemstones and, during his curatorship, the Museum first provided an annual acquisition budget, thus greatly enlarging the scope of mineral and gem purchases. In 1984, the traditional position of Curator was replaced by the dual positions of Research Scientist and Collection Manager. Lin concentrated on research and Joan Henley, who had been Oliver Chalmer's assistant, became Collection Manager. Together, Joan and Lin promoted gemstones, featuring them in displays and publications and during the 1980s the collection acquired a number of fine stones. Lin established a wide network of Australian and overseas contacts, many of whom are gemmologists. He is an Australian delegate to the International Gemmological Conference and the Australian representative on the International Mineralogical Association Commission for Gem Materials. During the 1990s Lin was the author of two books about gemstones, *Gemstones of the Southern Continents* and *Gemstones & Minerals of Australia*, both of which featured many stones from the Museum collection. The current Collection Manager, Ross Pogson, carries on the involvement with gemstones, with a particular interest in rare Australian material. An outstanding recent acquisition is a fine green fluorite from The Gulf, Emmaville, NSW.

The Prince of Minerals: a Tasmanian Treasure

P.A. WILLIAMS

For many mineralogists, crocoite, normal lead(II) chromate ($PbCrO_4$), is the Prince of Minerals. Localities on the west coast of Tasmania, especially around Dundas, have yielded exceptional specimens for more than a century and many of these grace mineral collections around the world. Chromium achieves its highest oxidation state in the mineral, Cr(VI), and crocoite exists at the limits of accessible geochemical environments (Crane et al., 2000). Crocoite has a rich chemical history dating from its discovery in the mid-eighteenth century; the new element chromium was isolated from it by Vauquelin in 1794 (Williams, 1974). Lead(II) chromate has been used extensively as a pigment (chrome yellow) although this application is less evident today.

Despite the fact that the chemistry of lead(II) chromate has been studied exhaustively, a number of enigmatic aspects have remained unexplored. Specific areas include structural relationships between the monoclinic mineral and its artificial orthorhombic polymorph, the extent of solid solution of sulfate in both phases and their relative stabilities. These areas have recently been addressed and many apparent inconsistencies in the literature rationalized (Crane et al., in press). Great differences exist in terms of solid solution behaviour for the two polymorphs and the orthorhombic phase is substantially less stable at room temperature than crocoite; it is unlikely that the former could persist in Nature as a mineral. Kinetic phenomena in the system are important and recrystallization of orthorhombic lead(II) chromate in contact with aqueous solutions is acid-catalyzed.

A number of these chemical subtleties are explored and extended to an evaluation of the geochemical settings in which crocoite and its congeners form. Other aspects of the mineralogy of chromate, including the chemical significance of chromatian cerussite, are discussed.

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From Icehouse to Hothouse: Australia, Past and Future - A Critical Review

P.R. EVANS

J.J. VEEVERS, *Atlas of Billion-year Earth History of Australia & Neighbours in Gondwanaland*, GEMOC (National Key Centre for the Geochemical Evolution and Metallogeny of Continents) Press, 2001. 76 pp., 92 figs. ISBN 0-646-40974-3.
Available from J.J. Veevers, Department of Earth & Planetary Sciences, Macquarie University, Sydney NSW 2109 Australia, phone (02) 9850 8355, john.veevers@mq.edu.au
Order form at http://www.es.mq.edu.au/GEMOC/BYEHA/page1.htm
AUS$30 incl. postage and GST, international: AUS$60 incl. postage.

JOHN L. DALY. *Still Waiting for Greenhouse. A Lukewarm View of Global Warming - from Tasmania.* http://www.john_daly.com/

During the last two centuries, in which Europeans have established a modern and distinctive society in Australia, the newcomers have faced the task of comprehending the nature of a continent that differs from all other major land masses in almost every respect. From the earliest days of colonisation the ways and means of scientific enquiry have played a major role in this process - to which the annals of Royal Society of New South Wales stand witness. Not only have such enquiries been shaped by the importance of understanding the physical and biological make up of the continent, but there has been a continuing drive to place Australia, the land and society, into a global context.

Both the need for the knowledge and Australian societal attitudes are well exemplified by the two recent and contrasting publications (above), one in the search to understand the geological history of the Australia (Veevers), the other to comprehend the complexities of climate change (Daly). The one looks to the past, the other to both the past and the future, their interests are intertwined. Both subjects are earth sciences with a fortuitous common factor: when, in 1912, Alfred Wegener first presented his ideas on continental drift and the past existence of the supercontinent Pangaea on which Veevers elaborates, he lectured at the University of Marburg, on meteorology, astronomy and "astronomic-geographic position-fitting for explorers". His intrepid expeditions to the Greenland ice-cap in 1906 and thereafter until his death in the field in 1930 established him as an expert on polar meteorology and glaciology. Wegener was a true earth scientist, responsible for the beginnings of what is now a major geological paradigm, and for major contributions to the science of climatology.

Prof. John J. Veevers and his colleagues at Macquarie University, Sydney, have endeavoured to "paint the big picture" about Australia's geological history since the late 1960s. In 1984 they achieved the remarkable feat of compiling *The Phanerozoic Earth History of Australia* (PEHA), published by Clarendon Press. In 2000 they widened the field, producing *Billion-year Earth History of Australia & Neighbours in Gondwanaland* (BYEHA), published by GEMOC Press, that incorporated data from the other Gondwana countries and indeed from the entire globe, and explaining geological events in Europe and North America as due to events within Gondwana and vice versa.

Neither PEHA nor BYEHA are designed for the general public. They have similar styles and are packed full of illustrations and carefully acknowledged references. They are unabashed works of scholarship published in the traditional manner. Perhaps the least digestible parts of these publications are the diagrams and maps that are essential components of any geological history. Most of these illustrations include remarkably large amounts of information, that in consequence makes them difficult to read, and they are burdened with lengthy captions by way of explanation and acknowledgement. For all their faults, the diagrams are essential and excellent links to both the equally terse and factfull text and to original sources of information.

In recognition of the need for a version more suited to a general audience, Veevers, as sole author and again via GEMOC Press, published in 2001 a 76 page version of the original 388 pages of BYEHA with 92 illustrations culled from the original and enhanced with the clever application of selective colouring under the title *ATLAS of Billion-year Earth History of Australia & Neighbours in Gondwanaland.* Veevers described this as a "pictorial primer" and claimed that "The atlas is aimed at those who want an affordable and up-to-date picture of Australia's tectonic and environmental heritage from the past billion years uncluttered by but's and if's or references". This is not a coffee-table book. It makes no concessions to the reader's lack of geological and geographical knowledge. The diagrams are not re-drafted or simplified, although their legends are abbreviated. A reader needs to be conversant with the fundamentals of geological paradigms and the geological composition of Australia and to have a grasp of Australian and world geography.

Modestly hidden towards the end of the original BYEHA, but placed to the fore in the ATLAS, is a model of long-term cyclic crustal and atmospheric evolution that Veevers originally published in 1990. It is Veevers' credo to which he makes frequent reference throughout the text. In this model, when most of the continental crust had coalesced to form Pangaea (Pangea), it was acting as an insulator to the "monsoonal" convective heat rising from the core via the mantle. According to Veevers, who followed the ideas of A.G. Fischer, the lessened volcanic activity at such a time resulted in the release of less of carbon dioxide into the atmosphere, leading to a lowered concentration of that gas and thence a cooler world and extensive glaciation. This situation is inherently unstable. Heat confined in the mantle by the blanket of Pangaea led to localised thinning of the lithosphere and eventual rupture and spreading of the crust once more. The increased turnover of the mantle is manifested at the surface as increased volcanism (forming new oceanic crust) and release of carbon dioxide leading to a hotter atmosphere. Veevers uses the work of his colleague Malcolm Walter and others on the variance in ratios of Sr isotopes through time, which they think to be indicative of global temperatures, and links it to the tectonic cycles. When the continents were thus assembled, the earth was an "icehouse" but when they were dispersing, the earth was a "hothouse". Veevers sees therein two 400 million-year Pangaean cycles, one starting 720 million years ago with the glaciations of the Neoproterozoic and the second 320 million years ago with the glaciations of the Late Carboniferous. Veevers discerns five stages in each cycle and allocates the events recorded in Australia's geological history accordingly.

The geological evidence for the past existence of two Pangaeas, which Veevers labelled Pangea A (the younger) and Pangea B, is compelling. The southern supercontinent, Gondwana, was created by the collision of east and west Gondwana, 650–580 million years ago (during the Neoproterozoic). Coalescence of Gondwana with the northern supercontinent, Laurasia, 320 million years ago (during the Carboniferous), resulted in the formation of Pangaea A and was the reason for the intracontinental mountain-building in the vicinity of Alice Springs in Australia. Veevers suggested that there was intra-crustal shortening at the site of the present day sub-glacial Gamburtsev Mountains and in the Beardmore-Ross Highlands, Antarctica. Antarctica was roughly in its present position over the South Pole. Rapid regional uplift of Pangaea (due to build-up of mantle heat) and the cooling atmosphere induced continent-wide glaciation and the spread of a dry-based ice sheet. Drainage patterns in Gondwana at the end of the Carboniferous and during the succeeding Early Permian Period (320–280 million years ago) radiated from these presumed centres of ice-sheets. In the Late Carboniferous a discontinuous ice sheet extended as far north as latitude 30°S and persisted for about 20 million years. Veevers makes the very important point that the Early Permian glacial sediments are evidence of glacial retreat, not of a glacial maximum. There was no glaciation worldwide during stage 4 of the cycle, 180–100 million years ago (mid-Jurassic to mid-Cretaceous), a time of maximum sea-floor spreading (and volcanism).

The central and western thirds of Australia and most of Antarctica were a cohesive continent (east Gondwana) 1000 million years ago (the beginning of the Neoproterozoic). Pangaea B was established 280 million years later. A broad sag developed in the crust in central Australia that connected to a rift in the crust in the region of Adelaide. Two major phases of glaciation are evident in sediments filling these depressions. The oldest glacial sediments, the Sturtian glacials, 700 million years old, were locally derived. The younger suite, the Marinoan glacials, were deposited 100 million years later and were more widespread. Correlatives of both glacial phases are found on other continents. Veevers assigns the Sturt glacials to Stage 2 in the Pangea B cycle and the Marinoan glacials to the base of Stage 3. Sedimentary characteristics and variations in ratios of the isotopes of C, S and Sr therein above and below the glacials, as presented by Malcolm Walter, indicate how cyclic the climate was even within these two stages. Palaeomagnetic evidence carries the remarkable inference that the Pangean B glacials were located close to the equator at the time of deposition. Veevers concludes that during both glacial phases the earth was largely covered with ice in which Hoffman and others imaginatively labelled as "Snowball 1" and "Snowball 2".

According to Veevers the world as it stands should now be towards the end of the Pangaea A cycle, but he does not venture to suggest that the glaciations of the past 1.8 million years (the Quaternary, or Pleistocene plus Holocene) mark the beginning of another cooling cycle. After all, the continents are too dispersed for the imminent creation of another Pangaea. Faithful to the central theme of "geological history", both BYEHA and the ATLAS record events towards the end of the Pangaean A cycle, through the 65 million years of the Cainozoic to the present day. Veevers includes a summary on "Quaternary Australia: extremes in the last glacial-interglacial cycle", by M.A.J. Williams (University of Adelaide). Williams graphically illustrates the story with curves representing variations in global climate and variations in the concentration of atmospheric carbon dioxide derived from a deep core into the Antarctic ice at the Russian research station at Vostok. Williams links fluctuations in carbon dioxide concentration with temperature and Milankovitch cycles, but draws no relationship with volcanism.

The success of BYEHA and the ATLAS stand on the wealth of direct observations and measurements that underpin the Australia Gondwana Pangaea geological and climatic history. The theory used by Veevers to frame his presentation is intriguing, but by no means widely accepted. It depends on a number of propositions, the chief of which is that any increase in atmospheric carbon dioxide concentrations causes global warming, a proposition that has caught popular and political attention.

The initial recognition that gaseous constituents of the atmosphere, namely water vapour and carbon dioxide, do much to determine the ambient temperature at the earth's surface is attributed to the chemist Svante Arrhenius. The increasing concentration of atmospheric carbon dioxide observed at Hawaii's Mauna Loa Observatory since 1958 is widely attributed to the increased combustion of fossil fuels since the beginning of the Industrial Revolution. From thence there have been various predictions that the increased carbon dioxide levels will increase global temperatures and generate dire consequences. The International Panel on Climate Change (IPCC), was established by the World Meteorological Organization and the United Nations Environment Programme in 1988 with a charter "...to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. It does not carry out new research nor does it monitor climate related data. It bases its assessment mainly on published and peer reviewed scientific technical literature."

The IPCC has three Working Groups and a Task Force (on National Greenhouse Gas Inventories): Working Group I (WGI) assesses the scientific aspects of the climate system and climate change, in particular that arising from human activities. Working Group II (WGII) addresses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it. Working Group III (WGIII) assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change. The outputs of WGII and WGIII clearly depend on the findings of WGI, that completed its First Assessment Report in 1990 and its Third Assessment Report in 2001. From the outset, although science-based the work of the IPCC must be deemed to be that of a political organisation. The Second Assessment Report, Climate Change 1995, provided key input to the negotiations, which led to the construction of the Kyoto Protocol in 1997.

In the Summary for Policy Makers issued by WGII in the Second Assessment Report were the key statements, "Policymakers will have to decide to what degree they want to take precautionary measures by mitigating greenhouse gas emissions and enhancing the resilience of vulnerable systems by means of adaptation." and "Policymakers are faced with responding to the risks posed by anthropogenic emissions of greenhouse gases in the face of significant scientific uncertainties." The international ramifications of the Kyoto Protocol are far reaching and could be disastrous if the Protocol's foundations are insecure. In spite of the application of the Precautionary Principle in the statements by WGII, the conclusions reached by WGI *must* be right.

The Chairman of IPCC, Robert T. Watson, in a summary given to the Sixth Conference of Parties to the United Nations Framework Convention on Climate Change on 19 July 2001 stated, "This paper is based on the conclusions of the most recent careful, objective and comprehensive analysis of all relevant scientific, technical and economic information by thousands of experts (natural scientists, social scientists and technologists) from the appropriate fields of science from academia, governments, industry and environmental organizations from around the world ...".

The "thousands of experts" are contradicted by signatories to "Statement by Atmospheric Scientists on Greenhouse Warming" presented to the UN conference in Rio de Janeiro, Brazil in 1992 by independent scientists researching atmospheric and climate problems and by the "Heidelberg Appeal", also released at the 1992 conference. By the end of the 1992 summit, 425 scientists and other intellectual leaders had signed the "Heidelberg Appeal". Since then, word of mouth has prompted hundreds more scientists to lend their support; today, it is claimed, more than 4,000 signatories, including 72 Nobel Prize winners, from 106 countries have signed the petition. The Kyoto Conference was presented with the "Leipzig Declaration" in 1997. Since 1998 the "Oregon Petition" has gathered 17,800 verified signatures. This battle of numbers and prestige has more recently entered the arena of national Academies of Science, seventeen of which, the Australian Academy of Science included, signed a joint statement early in 2001 endorsing the IPCC and saying the IPCC "represents the consensus of the international scientific community".

But do numbers, consensus and prestige make the findings correct? Climatology, like geology, requires input from many scientific disciplines. Are all supporters of the IPCC sufficiently knowledgeable to judge the climatologists' computer-based analyses and predictions? At the very least there is a significant body of dissenters, some of whom are undoubtedly spurred by their association with specific interest groups, but there are others with sufficient independent scientific knowledge and credentials to be taken seriously. One such critic is John Daly of Tasmania, not a professional scientist or researcher but a secondary college teacher and amateur meteorologist, who demonstrated his ability to understand the complexities of climate change by publishing in 1989 *The Greenhouse Trap* (Bantam Books), a simple exposition of the underlying scientific principles to the concept of greenhouse gases and global warming, accompanied by a persuasive argument that the fears engendered by contentions of looming disaster were misplaced. *The Greenhouse Trap* is no longer in print and was never in a position to have much impact on either scientific or popular thinking. As the influence of the IPCC increased, however, Daly took his reasoning onto the internet where, since 1996, he has independently maintained and funded a web site (`http://www.john_daly.com/`) that has gained a world-wide reputation as a focus for debate of this thorny topic.

Daly's site is a mix of styles, from short newspaper-like columns of opinion, through regularly updated charts of data to a series of carefully thought out articles, some by Daly, most by knowledgeable guest contributors, each illustrated as necessary and carrying a reference list. The articles range from discussions of such critical matters as the manner in which measurements of temperature are recorded and the data are selected and manipulated; limitations of the modelling procedures employed by the IPCC; examination of the discrepancies between surface measurements and satellite readings; the physics of oceanic circulations and the influence of the oceans on atmospheric temperature; the physics of temperature forcing by carbon dioxide; the essentials of equilibrium variance of carbon dioxide concentrations in the atmosphere and oceans with changing temperature; discrepancies between the increase in the production rate of carbon dioxide and the rate at which atmospheric concentrations of the gas increase; and many other subjects relating to the hypothesis that human-induced increases in atmospheric carbon dioxide are a threat to the earth's survival. Other articles focus on the alternate hypothesis that climatic changes are induced by fluctuations in solar radiation. Because the efforts of the IPCC Working Groups are firmly directed towards geopolitical aims, a history that offers some explanations for the UK's initial support for investigations of the underlying theory and establishment of the IPCC has an appropriate place on Daly's site. Likewise there is a place for a philosophical contribution on the nature and need for scepticism.

If printed there are over 1000 pages of A4-sized pages of discussion and information stored and available for study on Daly's web site. Just as importantly there are links to the many other sites now on the world wide web devoted to the contentious issues of atmospheric carbon dioxide and "global warming". Enough information and significant criticism is available via Daly's web site to demonstrate that the categoric statements of the IPCC's WGI must be seriously questioned. That is, confidence in the scientific foundations underpinning the Kyoto Protocol are much in doubt.

Unlike the traditional approach to scholarship, resulting in a book such as BYEHA and the ATLAS that may or may not be continued through new editions, web sites are inherently dynamic, and may be altered at will. In the past five months alone, Daly has updated his site at least twenty times in a cumulative process. He archives older material but it is still accessible. Web sites may have limitations as sources of scholarship. The immediacy of publication and power of revision rests solely with the author, who may not be constrained by the opinions of an editor or referees. Daly's style is direct and forceful, but clear. He observes the need for peer review by accepting and publishing any commentaries and criticisms offered as appendices to the articles. He makes good use of one of the main advantages of the web over the printed word, the use of hyperlinks, particularly to the basic data. A visitor to the site is able to directly check the validity of a statement thereon. Daly's web site may rightfully lay claim to being an important work of scholarship, albeit in a non-traditional format. Its effectiveness is being measured by the interest of at least 1000 visitors per day.

Perhaps the greatest limitation to any site of this nature on the web is the ephemeral nature of the medium. Not only may the content be altered at will, it could be withdrawn at a moment's notice. An example of Daly's work (23 Feb 2000 edition) is preserved by the State Library of Tasmania[1]. The significance of Daly's site probably justifies that it be preserved in the National Library's PANDORA electronic archive of Australian web sites[2]. It is an Australian example of the fable of the little boy and the king with no clothes, and is certainly an indictment of the extraordinary state we have reached where scientists are asked to follow the Orwellian demand that they capitulate to "the consensus of the international scientific community".

And what of the relationship between increases in carbon dioxide and increases in atmospheric temperature and Veevers' hypothesis that volcanism is a driving force? Daly points, for example, to evidence that at least on the shorter time scale of thousands (not millions) of years, changes in atmospheric temperature *precede* increases in carbon dioxide concentration, reverse to the requirement in Veevers' model (and removing one of the propositions on which the conclusions of the IPCC are based). Short-term perturbations of global temperatures brought about by volcanic eruptions are discernable in both surface and satellite records, but they are due to particulate emissions, not gaseous ones. It seems unlikely that Veevers' hypothesis relating tectonics to global warming will survive the test of time, although the relationship between plate motions and perturbations to the monsoonal heat flow of the mantle because of the episodic build-up of supercontinents still carries weight.

Alfred Wegener had the right attitude. In *The Origins of Continents and Oceans*, 4th edition, he stated "Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. ... It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw." The challenge before the modern world is to see that the rapidly increasing body of knowledge of the earth's composition, and history is appropriately applied. The two Australia-based authorities, John J. Veevers and John L. Daly, are playing a role in meeting that challenge by assessing, synthesising and disseminating critical components of that body of knowledge. John Daly goes one step further by pointing to the need to re-assess how that knowledge is currently being applied before it is too late.

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(Manuscript received 21.11.2001)

[1] http://www.statelibrary.tas.gov.au/odi/1atoz/s.asp
[2] http://pandora.nla.gov.au/index.html

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Thesis Abstract: Variation in the Anterior Mandible of Homo sapiens sapiens

GRAHAM KNUCKEY

Abstract of a thesis submitted for the Degree of Doctor of Philosophy,
November 2000 University of New England, Armidale,
New South Wales, Australia.

One of the features that distinguishes humans from all other primates is the presence of a symphyseal buttress, or chin, on the basal margin of the buccal surface of the mandible. The presence and purpose of this buttress has been debated for two hundred years, culminating at the end of the twentieth century, in two main branches of thought; the adaptive hypothesis and the non-adaptive hypothesis.

With the passing of time the human craniofacial skeleton has reduced in size and the lower facial skeleton (which includes the mandible) has moved in under the cranial vault becoming in turn, less prognathic. The adaptive hypothesis suggests the chin appeared in humans as an adaptive response to these changes in size and shape and argues that as the mandible reduced in size to accommodate broader craniofacial size reductions, a buttress of bone developed at the mandibular symphysis, as a means of strengthening the anterior mandible against masticatory muscle stresses. This buttress was unnecessary in larger, ancestral hominids because their mandibles were sufficiently robust to begin with.

The non-adaptive hypothesis, however, maintains the symphyseal buttress is merely an artefact of evolution and that it does not actually exist as an adaptive trait at all . Rather, as the alveolar growth field in the mandible receded more rapidly than the basal growth field below it, the buttress of bone simply appeared between the two. The non-adaptive theorists argue the buttress has no adaptive significance, yet they concede it may have developed a functional role since first appearing on the mandible of *Homo sapiens sapiens* (commonly referred to as modern *Homo sapiens*).

Both adaptive and non-adaptive arguments are based upon the same underlying principle - that through time the human craniofacial skeleton has reduced in size, resulting in a buttress of bone appearing over the mandibular symphysis below the incisors. This thesis explores the underlying principle further and presents a model that suggests that as a direct result of this principle, symphyseal buttresses (chins) should be more prominent in human populations that are on average small. Specifically, a reduction in the lower craniofacial skeleton in humans has produced a response from the basal section of the anterior mandible, which has become increasingly prominent. The research presented here argues the result of this process should be an increase in symphyseal prominence in smaller human populations - bigger chins in smaller groups.

The model is tested using samples of crania from human populations originating in the Aleutian Islands; Australia (Australian Aborigines); Egypt (Pre- and Late Dynastic periods); mainland North America (African Americans, Caucasians, and Native Americans); South Africa (Sotho and Xhosa language groups); and the United Kingdom (Romano-Britons). It demonstrates that populations which are, on average smaller, do possess more prominent chins. There is also circumstantial evidence in support of a trend toward more prominent buttresses in the more gracile individuals within human populations, that is, the females.

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The Clarke Medal 2000

SARAH ELIZABETH SMITH

Sarah Elizabeth Smith gained her first degree in the Botany School at Cambridge University (U.K.) and, following an M.A. there, was awarded her PhD in 1965 for a thesis on "The Ecology of Orchid Mycorrhizal Fungi". She remained at Cambridge as a post-doctoral Research Assistant for two more years before joining the Botany Department of the University of Adelaide in 1967.

By then she had married and for the first 6 years at Adelaide was tutoring part-time while raising two children. But from 1974, on being appointed Senior Teaching Fellow in Botany at Adelaide, her professional prowess was leaping ahead. Indeed, by the century's end she was justifiably being described as "renowned globally for her advances in the field of symbiotic relationships between fungi and plants" and further acclaimed as an inspirational world leader "not only in the field of Mycorrhizal research but also in other areas of Soil Biology and Soil Research".

Successively at Adelaide she became Research Fellow in Agricultural Biochemistry, then Senior Lecturer with a DSc by thesis in 1991, followed by a Readership in 1994. In 1995 she was appointed to a Personal Chair by the University and elected Head of the Department of Soil Science for a 3-year term. In 1998 she became Director of the University's Centre for Plant Root Symbiosis.

As is invariably the case with dedicated scientists, a list of Professor Sally Smith's achievements, such as research publications, international and home invitations to teach and give named lectures, collaborate in and supervise projects, and obtain support grants, can be up-to-date only briefly. However, as at September 2000 the list comprised 3 books, 2 edited volumes, 36 reviews and book chapters, 86 Conference presentations, and 101 research papers. That list is already incomplete.

Professor Smith is a worthy recipient of the Clarke Medal for 2000.

ECP

Read out at the Annual Dinner of the Royal Society of New South Wales (15-3-2001). Prof. Sarah Smith could not attend and the presentation was undertaken by the Royal Society of South Australia on behalf of the Royal Society of New South Wales.

Presentation of the Clarke Medal by the Royal Society of South Australia

At the Royal Society of South Australia's Ordinary Meeting on June 14th 2001, Prof. Sarah (Sally) E. Smith was presented with the prestigious Clarke Medal for 2000. This medal was awarded by the Royal Society of New South Wales and was presented on their behalf by President Neville Alley. Members were given an overview of her research interests and achievements and were enthusiastic in their applause for this prominent Australian scientist. Her presence at the meeting allowed past colleagues and friends the opportunity ot offer congratulations.

Prof. Smith's scientific career has been long and distinguished. After studying at Cambridge University for her PhD on "The Ecology of Orchid Mycorrhizal Fungi" and remaining for two further postdoctoral years, she joined the University of Adelaide's Botany Department in 1967. She became a senior teaching fellow in that department in 1974 and eventually Research Fellow in Agricultural Biochemistry. Prof. Smith went on to become Senior Lecturer with a DSc in 1991, followed by a Readership in 1994, appointment to a personal Chair in 1995 and Head of the Department of Soil Science at the same university. In 1998 she became Director of the University's Centre for Plant Root Symbiosis.

Prof. Sally Smith's achievements are reflected in her long list of research papers (101 as of 2000), books (3), edited volumes (2) and numerous conference presentations, reviews and research grants. She has supervised many postgraduate students and hosted several visiting researchers.

Her current research interests include the development and function of vesicular arbuscular mycorrhizas, orchid mycorrhizas, and root growth. She is chiefly interested in the analysis of the processes involved in the development and function of mycorrhizal infection in plant root systems.

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Edgeworth David Medal 2000

MICHAEL SOON YOONG LEE

Michael Lee has made numerous internationally-recognized contributions to the fields of evolutionary biology and palaeontology.

He graduated from the University of Cambridge with a PhD in Zoology in 1995 following an outstanding academic record at the University of Queensland. His thesis was entitled Evolutionary morphology of pareiasaurs.

Since completing his doctorate, he has held ARC postdoctroal research fellowships, first at the University of Sydney and then moving to his present position as QEII Fellow at the University of Queensland in 1998. He won a Fulbright Award in 1998.

His research revolves around the systematics and evolutionary biology of reptiles. Major research projects include the anatomy and relationships of lizards and snakes, their origins and fossil records and the evolution and reduction of limbs. He has been particularly innovative in integrating molecular and morphological approaches to phylogenetic reconstruction, using RNA and DNA nucleotide data as well as behavioural and palaeontological records. He has made a number of important contributions to conservation biology through phylogenetic approaches involving correlation of morphological and genetic indicators in various groups of reptiles. His success in winning two large ARC grants in one measure of the significance of this work on the origin of snakes and novel molecular approaches to inferring vertebrate phylogeny.

Michael's work on the early evolution of snakes featured recently on the cover of Nature. This edition contains an article with John Scanlon on the pleistocene serpent Wonambi, one of the most primitive snakes known, which sheds light on the relationships between snakes and lizards and the development of the snake body form and contradicts the widely held "subterranean" theory of snake origins. In another letter in Nature with Gordon Bell and Michael Caldwell, he presents evidence to fill a gap in the evolutionary chain from the relatively inflexible lizard skull to the highly mobile snake skull through a family of large extinct marine lizards.

He has published 26 research papers in scientific journals and a number of popular pieces. His work has been celebratedint he media in the Australian and the New York Times.

Michael Lee is a young scientist who has built up an impressive track record in probing fundamental questions about the evolution of species, a field which was of great interest to Edgeworth David himself. He is a worthy recipient of the Edgeworth David Medal.

JL

The Edgeworth David Medal for 2000 was awarded to Dr Michael Soon Yoong Lee and presented to him by the Royal Society of South Australia on behalf of the Royal Society of New South Wales. The presentation took place on the 11th October 2001 at Urrbrae House, Adelaide SA. in conjunction with several other presentations (such as the Verco Medal) by the Royal Society of South Australia. Dr Michael Lee, now a resident of South Australia, joined the Royal Society of South Australia.

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The Society's Medal 2000

PHILIP RICHARD EVANS

Philip Richard Evans was educated in Britain. He read Geology at Oxford and carried out postgraduate studies in paleontology and stratigraphy at Bristol. In 1957 he was recruited by the Australian Bureau of Mineral Resources (BMR), Canberra, to study marine organic walled microfossils, that were proving to be of value elsewhere in the world in resolving stratigraphic problems. In the same year the Commonwealth Government instigated the Petroleum Search Subsidy Act and BMR was charged with monitoring the work of the exploration companies, that received Commonwealth support thereby. He analysed samples from subsidised exploration wells to check if the stratigraphy reported by the drilling companies was correct. Few of the wells were drilling rocks of marine origins and he was obliged to extend his interests into the more prevalent fossil spores and pollen that were released by the same extraction process. The available taxonomic and stratigraphic database with which to draw comparisons was extremely limited or non-existent, and the demand for quick results was high. Richard was obliged to develop both taxonomic and stratigraphic schemes from scratch and in the process he examined material that ranged in age from the Proterozoic to the Cretaceous. He always saw the study of organic walled microfossils (now generally referred to as palynology) as a means to an end - the establishment of a region's stratigraphy and geological history.

Exploration in the late 1950s and early 1960s was entirely onshore, mainly in Western Australia and Queensland. Richard concentrated his work on eastern Australian drilling. He cooperated with the Commonwealth sponsored Institut francais du Petrole's mission to Australia and entered into major controversies over the subsurface stratigraphy of the Great Artesian Basin and its infra-basins, and established a stratigraphic frame of reference through the Permian to Cretaceous, based on the distribution of a diversity of organic walled microfossils that proved useful throughout eastern Australia. He also pioneered studies in eastern Australia of the correlation of spore/pollen colouration with the regional maturation of potential petroleum source rocks.

In 1967 Richard left BMR to join Esso-BHP's offshore exploration projects in Bass Strait, where he cooperated in the development of a palyno-stratigraphical scheme of subdividing the oil-bearing Late Cretaceous-Early Cenozoic Latrobe Group in the Gippsland Basin and correlatives in related Basins. Richard moved to Sydney and set up his laboratory in the Department of Applied Geology at the University of New South Wales, the beginning of a long association with that University. As exploration progressed, it became evident that there was a very close tie between the palynological results and stratigraphic evidence gleaned from reflection seismic studies. The combined fossil and geophysical evidence greatly enhanced modelling of basins and Richard broadened his skills to include seismic interpretation and seismic stratigraphy.

In 1970, Esso moved Richard to the company's basins studies group. He relinquished direct palynological work and joined and eventually headed a group interest in acreage evaluation and acquisition, particularly in Western Australia. When political forces in 1975 brought exploration temporarily to a halt Richard was offered a position with Exxon in the USA, but he preferred to stay in Australia and was fortunately offered a lecturing position among old friends at UNSW. Until his retirement in 1991, Richard spent 16 years at UNSW teaching and researching into diverse aspects of Australian sedimentary basins and their petroleum potential. Always with a view to both broadening his experience and making useful contributions therefrom, Richard as a consultant also undertook studies around the Pacific rim that ranged from offshore Hainan Island, China, through onshore northern Thailand to deep water off New Zealand.

Richard Evans has been a member of the Royal Society of New South Wales since 1968. When in retirement, he was inveigled to become an Hon. Secretary to the Society's Council in 1997/98. He became closely involved in the Society's affairs, volunteering to act as Hon. Treasurer in 1999/2000 and Hon. Secretary again in 2000/2001, as well as Acting Hon. Treasurer.

Outstanding scientific achievements and sterling work for the Society surely merit this award of the Society's Medal for 2000 to Dr Philip Richard Evans.

DJS

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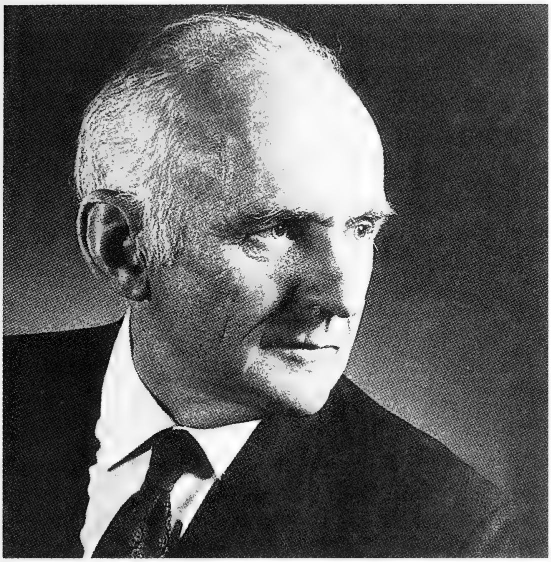
Biographical Memoirs



Sir RUTHERFORD NESS ROBERTSON
1913–2001

Sir Rutherford (Bob) Robertson was born in Melbourne. His father was a Baptist minister and his mother had a natural curiosity and an interest in science. He suffered polio in childhood. He went to Sydney University and studied Chemistry and Botany. After graduating, he received a Science Research Scholarship and a Linnean Macleay Fellowship which allowed him to continue doing research for three years. He studied the stomata (leaf pores) of plants of the Sydney region.

An 1851 Exhibition scholarship allowed him to go to Cambridge University where he studied the transport of nutrients around plant cells. He married Mary Rogerson in 1937 and gained his PhD in 1939. He returned to Sydney University and became an assistant Lecturer in Botany. After the start of World War II, which restricted shipping, he collaborated with CSIR (later CSIRO) on better ways of storing apples, pears and wheat.

In 1946 he was invited to head the plant physiology and fruit storage section of CSIR, which then had laboratories in Homebush Abattoir. He negotiated with the Botany Department of the University of Sydney to pool resources for a plant physiology unit. During the 1950's he continued to explore the link between plant respiration, which produced energy, and active transport of charged particles, which consumed energy. This was cutting edge science at the time.

Bob Robertson was invited to join the CSIRO executive. In 1962 he decided to return to a position where he could do his own research. He became Professor of Botany at Adelaide University. His time for his own research was short-lived, for in 1965 he became part-time chairman of the Australian Research Grants Committee, which allocated research funds. In 1969 he became Master of University House at the Australian National University, which gave him the chance to do his own research.

He became President of the Australian Academy of Science in 1970, having been elected to the fellowship soon after the Academy was formed in 1954. While President, he led a group that discussed with French scientists the atmospheric testing of nuclear weapons in the Pacific. They disagreed on the likely effects. He became director of the ANU Research School of Biological Science in 1973 and continued to follow his research interests. He retired in 1978.

Bob Robertson was knighted in 1972 and became a Companion of the Order of Australia in 1980. In retirement, he continued as Deputy Chairman of the Australian Science and Technology Council and Pro-Chancellor of the Australian National University. He continued his research at the University of Sydney until 1986. He made a lasting contribution to science through his own research, his leadership of others and his influence in university and government administration.

He is survived by his wife Lady Robertson and his son Robert.

Acknowledgements: The above is reproduced with the permission of the Linnean Society of New South Wales.

LOUIS WALTER DAVIES AO

1923 – 2001

Louis Walter Davies was born on the 27 August 1923 at Aberdeen in New South Wales. It seems that from his earliest days at the little country primary school at Aberdeen Lou Davies was interested in and good at mathematics and enjoyed doing science experiments. After high school (Sydney Church of England Grammar School, North Sydney) he continued his education at the University of Sydney. The second World War interrupted his studies. He joined the Royal Australian Air Force and as navigator flew 52 operational reconnaissance sorties in Beauforts over the islands to the north of Australia followed by a second tour in Dakotas.

After the war Lou Davies continued his studies at the University of Sydney obtaining a BSc degree majoring in mathematics and physics. His undergraduate studies earned him several prizes which, combined with an outstanding war record and his sporting prowess, led to the prestigious Rhodes Scholarship in 1948. He married June Fleming in September 1945 and both proceeded to Oxford University. There Lou worked in the Clarendon Laboratory on plasma physics and thermonuclear fusion. He was awarded a Doctor of Philosophy for this work by the University of Oxford.

Accompanied by his wife and son he returned to Sydney in 1951 to take up a research appointment in the CSIRO Radiophysics Laboratory continuing his plasma physics work by studying noise radiation from gas-discharge columns.

The emerging developments in semiconductor physics such as transistors and the growing of germanium crystals captured his interest and led to six weeks working at the famous Bell Telephone Laboratories in Murray Hill US.

Sir Lionel Hooke, Chairman of AWA offered Dr Davies a position as Chief Physicist to work on semi-conductors.

From then on he, for almost a quarter of a century, worked on a wide range of topics: 1962 he pioneered work on optical fibres followed by work on integrated circuits, surface acoustic waves, elecrostatic precipitation, electrets, reliability physics and engineering, hazard analysis and safety engineering as well as solar energy conversion.

Having become Chief Scientist and Head of the AWA Research Laboratory and for three years President of the Australian Industrial Research Group, Dr Davies then, for seven years, served as a member of the ASTEC (Australian Science and Technology Council of the Australian Commonwealth).

In 1965 he became a Visiting Professor of Electrical Engineering at the University of New South Wales and Head of the Solid State Electronics Department. His work on photo-voltaics and solar energy was outstanding. Thus on his retirement the Council of the University of New South Wales appointed him emeritus professor. Further recognitions were elections to Fellowships of the Australian Academy of Science, the Institute of Electrical and Electronics Engineers New York, USA (1981), and the Australian Academy of Technological Sciences and Engineering.

He was appointed an Officer in the Order of Australia in 1978. Professor Davies joined the Royal Society of New South Wales in 1997 as a member of the Southern Highlands Branch. Louis Davies died on the twenty ninth of September 2001. He is survived by this wife June and three children.

(compiled from information kindly supplied by Sir Rupert Myers, KBE, AO, FTSE, FAA)

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THE ROYAL SOCIETY OF NEW SOUTH WALES

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The Society originated in the year 1821 as the Philosophical Society of Australasia. Its main function is the promotion of Science by: publishing results of scientific investigations in its *Journal and Proceedings*; conducting monthly meetings; organising summer science schools for senior secondary school students; awarding prizes and medals; and by liason with other scientific societies. Special meetings are held for: the Pollock Memorial Lecture in Physics and Mathematics, the Liversidge Research Lecture in Chemistry, the Clarke Memorial Lecture in Geology, Zoology and Botany, and the Poggendorf Lecture in Agricultural Science.

Membership, as an Ordinary, Associate or Absentee Member, is open to any person whose application is acceptable to the Society. An application must be supported by two members of the Society. Subscriptions for the Journal only are accepted. The Society welcomes, from members and non-members, manuscripts of research and review articles in all branches of science, art, literature and philosophy for publication in the *Journal and Proceedings*. Manuscripts from non-members must be communicated through a member.

ISSN 0035-9173

NOTICE TO AUTHORS

Manuscripts should be addressed to The Honorary Secretary, Royal Society of New South Wales, PO Box 1525, Macquarie Centre, NSW 2113. Manuscripts submitted by a non-member (through a member) will be reviewed by the Hon. Editor, in consultation with the Editorial Board, to decide whether the paper will be further considered for publication in the Journal.

Manuscripts are subjected to peer review by an independant referee. In the event of initial rejection, manuscripts may be sent to two other referees.

Papers, other than those specially invited by the Editorial Board on behalf of Council, will only be considered if the content is substantially new material which has not been published previously, has not been submitted concurrently elsewhere nor is likely to be published substantially in the same form elsewhere. Well-known work and experimental procedure should be referred to only briefly, and extensive reviews and historical surveys should, as a rule, be avoided. Letters to the Editor and short notes may also be submitted for publication.

Three, single sided, typed copies of the manuscript (double spacing) should be submitted on A4 paper.

Spelling should conform with "The Concise Oxford Dictionary" or "The Macquarie Dictionary". The Systéme International d'Unites (SI) is to be used, with the abbreviations and symbols set out in Australian Standard AS1000.

All stratigaphic names must conform with the International Stratigraphic Guide and new names must first be cleared with the Central Register of Australian Stratigraphic Names, Australian Geological Survey Organisation, Canberra, ACT 2601, Australia. The codes of Botanical and Zoological Nomenclature must also be adhered to as neccessary.

The Abstract should be brief and informative.

Tables and Illustrations should be in the form and size intended for insertion in the master manuscript - 150 mm x 200 mm. If this is not readily possible then an indication of the required reduction (such as 'reduce to 1/2 size') must be clearly stated. Half-tone illustrations (photographs) should be included only when essential and should be presented on glossy paper.

Maps, diagrams and graphs should generally not be larger than a single page. However, larger figures may be split and printed across two opposite pages. The scale of maps or diagrams must be given in bar form.

Half-tone ilustrations should be included only when essential and should be presented on glossy paper.

All tables and illustrations should be numbered consecutively with Arabic numerals in a single sequence and each must have a caption.

References are to be cited in the text by giving the author's name and year of publication. References in the Reference List should be listed alphabetically by author and then chronologically by date. Titles of journals should be cited in full - not abbreviated.

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The journal is printed from master pages prepared by the LaTeX typesetting program. When a paper has been accepted for publication, the author(s) will be supplied with a guide to acceptable electronic format for the submission of the revised manuscript. Galley proofs will be provided to authors for final checking prior to publication.

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