AUSTRALIAN EARTHQUAKE ENGINEERING SOCIETY CONFERENCE
EARTHQUAKE CODES IN THE REAL WORLD
Canberra, November 2001.

LAKE GEORGE EXCURSION NOTES
23rd November, 2001

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1. INTRODUCTION

The regional landscape of eastern Australia prior to the Tertiary (> 65 Ma) was a broad, deeply weathered plain (Ollier, 1978, 1982). Subsequent tectonic instability broke up this landscape into parallel tilted fault blocks. The faults formed small tectonic depressions that filled with fluvio-lacustrine sediments.

The Lake George Basin, situated about 40km northeast of Canberra, is interpreted to be such a tectonic depression. The basin is 68km long in a north-south direction and 19km in width, covering approximately 930km^2. Its margin is defined topographically by the Great Divide to the east and to the west by the continuous escarpment of the Cullarin Range. In the vicinity of Lake George the escarpment reaches up to 200m above lake bed level. This feature gives way to more subdued and rounded topography north of Collector and south of Bungendore. The escarpment is thought to reflect normal displacement across a structure denoted the Lake George Fault.

Only small earthquakes have occurred in proximity to the Lake George Fault since measurement began. The largest at magnitude 3.6 occurred at 9.25 am E.ST on 25 January 1967 and was 2 km east of the surface trace of the fault and 4 km SSW of Collector.

The excursion will inspect aspects of the late Cainozoic sedimentary sequence and view the geomorphology in terms of a model for the history of the basin. Additional features of interest such as recent seismicity, bedrock geology and hydrogeology will be discussed as appropriate en route. A map of the excursion route will be distributed at the conference.

2. BEDROCK GEOLOGY

The pre-Cainozoic geology comprises rocks belonging to the Lachlan Fold Belt. A thick pile of marine turbidite sediments of Middle to Upper Ordovician age is overlain unconformably by late Silurian acid volcanics and early Devonian turbidite units. The sedimentary rocks have been invaded by different generations of Siluro-Devonian acid and basic intrusions. The sequence was folded, faulted and weakly metamorphosed by a series of Palaeozoic earth movements (seen in the cutting at the lookout at Geary's Gap). The Ballallaba and Lake George faults are likely to have formed during the latest of these movements. Their association with basic intrusions and volcanics is typical of a rift zone environment (they formed as normal faults but may have reversed sense later).

3. LAKE GEORGE BASIN HISTORY

Basin Formation

Prior to the Tertiary the lake George area was part of a moderately dissected landscape with major drainage lines directed towards the northwest. The basin was initiated in the late Miocene by movement along the Lake George Fault zone. Normal faulting along this zone and perhaps other meridional fault lines to the east is evidenced by truncated northwesterly drainage lines in the headwaters of the Yass and Lachlan drainage basins (Taylor, 1907; Ollier, 1978; Abel, 1985).

Stream capture is demonstrated by the barbed drainage pattern of Collector and Tarago Creeks. The faulting which formed Lake George Basin blocked the upper catchment and these diverted creeks now bend acutely south and drain towards Lake George. West of the Lake George Range the topographic maps show these creeks line up with Frankfield, Lerida and Meadow Creeks, which drain northwest towards the Lachlan River.

Another equally dramatic example of stream modification by faulting is afforded by Shingle House Creek. This creek was once contiguous with Butmaroo Creek, which was part of a much-enlarged Yass River headwater system. Movement on the Lake George Fault blocked this headwater system. Westward tilting of the fault block west of the escarpment allowed Shingle House Creek to maintain its course towards the Yass River. Geary's Gap remains as a wind gap; the site of the original course of Shingle House/Butmaroo Creek.

Sedimentary Geology

The Cainozoic sediments in the Lake George basin record a fluvio-lacustrine sequence beginning in the late Tertiary (late Miocene) and extending into the Quaternary. From drilling results it is estimated that the total thickness of the sequence approaches 200m.

During its early history the basin functioned as a sediment trap for the deposition of fluvial sands and gravels (Gearys Gap Formation) with the drainage outlet at Gearys Gap being maintained. The relatively gradual change from fluvial to lacustrine conditions shown by cores and geophysical logs (collected by the BMR during a period of low lake level in 1982-1983, Abel, 1985) depends on factors such as basin subsidence brought on by gradual movements along the Lake George Fault zone and changing climatic conditions. By about the late Tertiary onwards tectonism was sufficient to have raised the spillway threshold at Gearys Gap. The result was the final truncation of drainage, formation of a greatly enlarged lake and the deposition of clay and silt (Lake George Formation). Dating results suggest that the Lake George internal drainage basin was established by the Pliocene (~1.8 - 5Ma; Singh et al., 1981).

The lacustrine sediments in the lake bed contain plant microfossils reflecting a complete record of the palaeoclimate over the last 350,000 years (Singh et al., 1981). This interval includes four glacial/interglacial cycles. The deeper parts of the sedimentary sequence have not yet been dated. Abandoned shoreline features (including the Woolshed embankment) up to 37m above the lake bed indicate a history of substantial water-level fluctuations dating back to the last glacial maximum (~27,000 years B.P., Coventry, 1976).

Geomorphology

With the exception of Gearys Gap, the present day morphology of the lake area is mostly a reflection of its late Quaternary history (<1.8Ma). The curved shape and steepening of the escarpment adjacent to Lake George is attributed to lake shore abrasion at times of high lake levels in the late Quaternary (Jennings, 1972; Coventry, 1976). The steep escarpment slopes are mantled by colluvial slopewash deposits, which have been dissected by more recent drainage forming alluvial fans at the foot of the escarpment.

Since the Quaternary alluvial deposition has continued along major streams, but in Recent times with the advent of settlement, land subdivision and clearing, gully erosion and sand mining there has been alteration of the landscape. The alluvium around the lake is an important source of sand and gravel for Canberra development, and contains aquifers that supply water to Bungendore and the former Woodlawn Mine.

4. HYDROLOGY

When Lake George is 'full' (taken to mean approximately 4.5-7m deep), it is the largest natural inland fresh water lake in Australia, covering some 155km^2. Precise lake levels have been monitored more or less continually since 1885, although sporadic records are available as far back as 1820.

Abondoned shoreline deposits at the northern and southern ends of the lake, up to 37m above the present lake bed, suggest significant fluctuations in lake level. The origin of the fluctuation has historically been a topic of great speculation. A popular theory was the draining of the lake water through a fissure and it's subsequent refilling from an underground spring.

Detailed monitoring and computation of the water balance has been undertaken by AGSO – Geoscience Australia (formerly BMR) since 1958 (Burton, 1972; Burton & Wilson, 1973). The results show that fluctuations are a response to seasonal and long-term variations in rainfall, evaporation and inflow of streams (Jacobson & Schuett, 1979). Salinity of the lake water was found to vary inversely with water volume.

5. THE LAKE GEORGE FAULT

The surface trace of the Lake George fault cannot be located in the field because the base of the escarpment is blanketed by colluvial and alluvial fan deposits. Its marked position is therefore approximate.

In order to test the basin-formation model, and define the bounding fault, gravity and seismic refraction surveys were conducted by the BMR over the Lake George Basin in 1963 and 1964 respectively (Kevi, 1963; Polak & Kevi, 1964). While they revealed that the sedimentary package within the basin thickened towards the escarpment, consistent with the fault angle depression model, they failed to unequivocally identify the Lake George Fault. However, Traverse B of the seismic survey revealed a bedrock surface geometry consistent with the presence of a number of rotated normal fault blocks beginning at the escarpment and extending to the east. The major offset is considered likely to have occurred proximal to the location of the escarpment.

A steep easterly dip for this major structure is assumed based upon the normal faulting model and the seismic interpretation. This orientation is also consistent with the structurally similar Queanbeyan Fault, a fault who's escarpment is sectioned in an abandoned road cutting immediately east of Queanbeyan township.

Assuming that quartz gravels at the top and bottom of the Lake George escarpment are correlatives then a minimum displacement for normal faulting downthrown to the east is approximately 100m. Based upon the relative heights of the Ordovician bedrock surface on each side of the fault, the offset may be as much as 280m.

The association of basic intrusive rocks with the Whiskers and Lake George faults has been taken as evidence that the faults extend through the entire thickness of the crust and permitted basic magmas to ascend through the crust (Abel, 1985). The Lake George Fault, while poorly defined, is therefore none-the-less a significant crustal-scale feature.

6. SEISMICITY

Historic Seismicity (Michael-Leiba, in Earthquakes in the Canberra Region - AGSO pamphlet)

No large earthquakes have occurred in proximity to the Lake George Fault in recorded history. The largest ML 3.6 as mentioned earlier was on 25 January 1967.

This earthquake was not mentioned in the Canberra Times, Evening Post (Goulburn), Queanbeyan Age or Yass Tribune so, in early March 1996, telephone interviews were conducted with residents of the Gearys Gap area who were there at the time of the earthquake. A resident about 20 km SSW of the epicentre heard and felt it. She said that it was the second strongest she had experienced since moving to the district in the early 1930s. She was inside at the time. The shaking was very strong and there was a roaring sound like a truck dumping gravel. The earthquake produced cracks in plaster in the section near the ground of external stone and plaster chimneys of their old house.

Another resident said that a crack in their brick lounge room wall, which incorporates a chimney, may also have been caused by this earthquake. He lives about 23 km SW of the epicentre. A lady on a property about 20 km SW of the epicentre thought she had felt the earthquake but that it was not very severe.

Between 1984 and 1992 the only two earthquakes recorded on the section of fault beside Lake George were of magnitude MD 1.0 and 1.3. They occurred at 12.11 and 12.31 am local time on 11 January 1992. MD is a magnitude based on the duration of the earthquake on a seismogram. It is an approximation for the Richter magnitude ML which is calculated from the maximum trace amplitude of the earthquake on the seismogram.

In 1993 a third small earthquake occurred on the Lake George Fault, near the western margin of Lake George, and 32 km NE of the Canberra GPO. The 1993 event occurred at 10.39 am E.A.S.T. on 18 June and had a magnitude of MD 2.0. It was heard and felt by residents near the epicentre. Closest to the epicentre, it was described by a resident as `an almighty bang as though something hit the house'. She actually heard a series of three bangs in quick succession with the first being the loudest. Two to 3 km south of the epicentre, it was experienced as ``a bit of a rumble'' which shook the house. Nine to 10 km SSW of the epicentre, a woman playing the piano felt it momentarily and said it sounded like a loud truck and wall beams creaked. Thirteen to 14 km ESE of the epicentre, the earthquake was reported felt like a big explosion. There was a loud noise and a shake with only the fly screens rattling a bit.

At 5.32 am E.A.S.T. on 24 March 1995, a magnitude ML 1.6 event occurred 2 km east of the eastern margin of Lake George, or 10 km east of the surface trace of the Lake George Fault. It was heard and felt near the epicentre. One person said that it sounded like a big clap of thunder. Another heard the rumble coming, felt a shake, then heard it rumble away.

It is important to note that uncertainties in earthquake locations in the Canberra region can be as large as 5-10 km. This makes it difficult to state with certainty that an earthquake is associated with a particular fault.

Causes for seismicity

Determinations of the seismogenic stress field in the south eastern Australia suggest NW-SE directed compression in the Lake George area (e.g. Denham et al., 1981; Hillis & Reynolds, 2000; Clark & Leonard, 2001). The Lake George Fault is therefore unlikely to have formed under the current stress conditions. Instead, it is likely that the minor seismicity recorded in the area reflects limited reactivation of the originally normal Lake George Fault (or related faults) in a reverse sense. Evidence for reactivation of pre-existing faults under the current stress conditions in the area is seen in the inconsistent pattern of pressure axes derived from the focal mechanisms of earthquakes at nearby Dalton and Gunning (Denham et al., 1981).

DRAFT ITINERARY

STOP 1: Australian Regional museum

STOP 2: Brooks Creek

STOP 3: Gearys Gap

Geary's Gap is a low saddle about half way along the escarpment. At its lowest point it forms a V-shaped notch about 0.5km wide lying 30-40m above lake level. The notch forms the centre of a wider depression, spanning some 4km and containing relict terrace deposits of quartz gravel. The depression is interpreted to be the remains of the old Yass River valley prior to its truncation by faulting (Taylor, 1907; Ollier, 1978).

STOP 4: Lunch and the Lake George Escarpment and the lake
The lake bed is approximately 674m above sea level.

STOP 5: Woolshed embankment

STOP 6: Bungendore

STOP 7: Canberra Airport