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TIDAL DEVIATIONS OF THE VERTICAL AT ARMIDALE, AUSTRALIA

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SUMMARY

Deviations of the vertical are being recorded at the Cooney Geophysical Observatory near Armidale, New South Wales, using a pair of Verbaandert - Melchior horizontal pendulums. Problems associated with the installation and operation of the apparatus have been largely overcome. Since the pendulums were installed in 1971 only two periods of reliable records longer than 29 days have been obtained. These data have been scaled and will now be forwarded to the International Centre for the Earth Tides for detailed analysis. Various non-tidal effects still appear on the current records and are probably due to site defects.

INTRODUCTION

Since 1961 the International Association of Geodesy has repeatedly recommended that earth tides should be recorded in the southern hemisphere, and particularly in Australia at the antipodes of Europe.

Although more than 300 stations are now observing earth tides, the stations are not uniformly distributed internationally. Central Europe is comparatively well-served with stations which have records extending over many years. Significant data have been obtained from a number of stations across the USSR, in Japan, and in North America. It is known that various groups in Australia, New Zealand, South America, and Antarctica are attempting to record reliable earth tide signals, but, as far as the authors are aware, no earth tide data from the southern hemisphere have yet been published.

This paper describes the installation and operation of a pair of Verbaandert-Melchior horizontal pendulums in the Cooney Geophysical Observatory near Armidale, New South Wales. This is a co-operative project by the Bureau of Mineral Resources, Geology and Geophysics (BMR) and the Department of Geophysics, University of New England (UNE) to measure tidal deviations of the vertical.

It was expected that analysis of recent data would be completed in time for presentation at this conference, but unavoidable delays have made this impossible. Nevertheless, continuous recordings from both pendulums have been obtained over two periods of more than 29 days, and the data have now been scaled and are being checked before transmittal to the International Centre for the Earth Tides for detailed analysis.

In common with other groups seeking to obtain reliable observations of the tidal variation in tilt we have experienced considerable difficulty in the installation and operation of apparatus. It is clear that the present site is not ideal, and non-tidal effects continually appear in the records.

Preliminary analysis of the data showed that the principal components of the tides can be separated, but that it may be difficult to determine their amplitudes and phases to the desired accuracy.

INSTALLATION OF THE PENDULUMS

The Verbaandert-Melchior horizontal pendulums ORB 53 and ORB 54 were obtained by BMR from Professor Paul Melchior in 1963. Because of difficulties in obtaining a suitable site and because of the unavailability of staff for this project the pendulums remained unused for some years. In 1970 UNE established the Cooney Geophysical Observatory in an abandoned mine in the Hillgrove area 28 km east of Armidale (see Fig. 1). BMR and UNE agreed to install and operate the pendulums as a co-operative project at that site.

The Cooney Observatory has been described in several earlier papers (e.g. Green and Sydenham, 1971) and is shown in Figs 2, 3, and 4. The pendulums are installed at the innermost end of the Upper Cooney tunnel about 170 m from the tunnel mouth so that the rock cover exceeds 100 m. The pendulums are isolated from the main part of the tunnel and the cross-cut by three brick partitions with sealing doors, so that the occasional ventilation of other parts of Upper Cooney do not produce significant temperature variations in the pendulum observation chamber.

As far as possible the installation follows the procedures laid down by Melchior (1966). A niche measuring 0.4 by 0.4 by 0.8 m was cut into the end face of the tunnel without the use of explosives. The rock is a garnetiferous carbonaceous slate and is extremely hard. Sets of fracture planes in three directions are clearly seen in the rock floor of the niche. Water weeps into the niche through various fractures, and has caused considerable difficulty. The pendulums are mounted on stainless steel pins glued with Araldite into holes drilled into the floor of the niche. As recommended by Melchior great care was taken

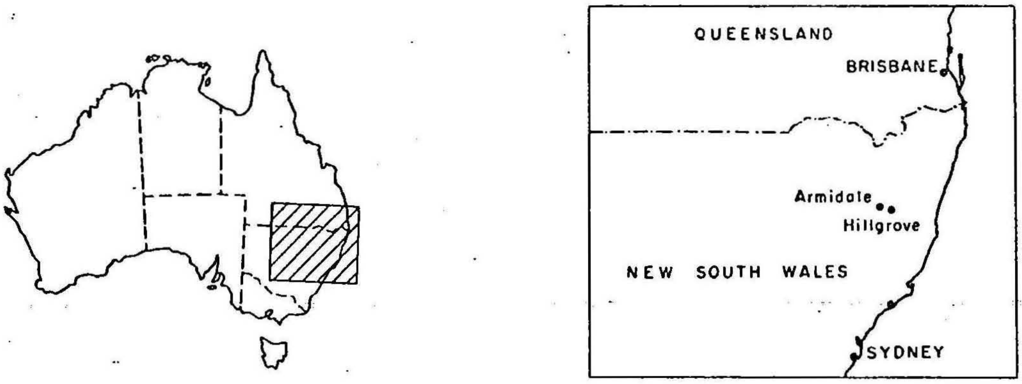

Figure 1

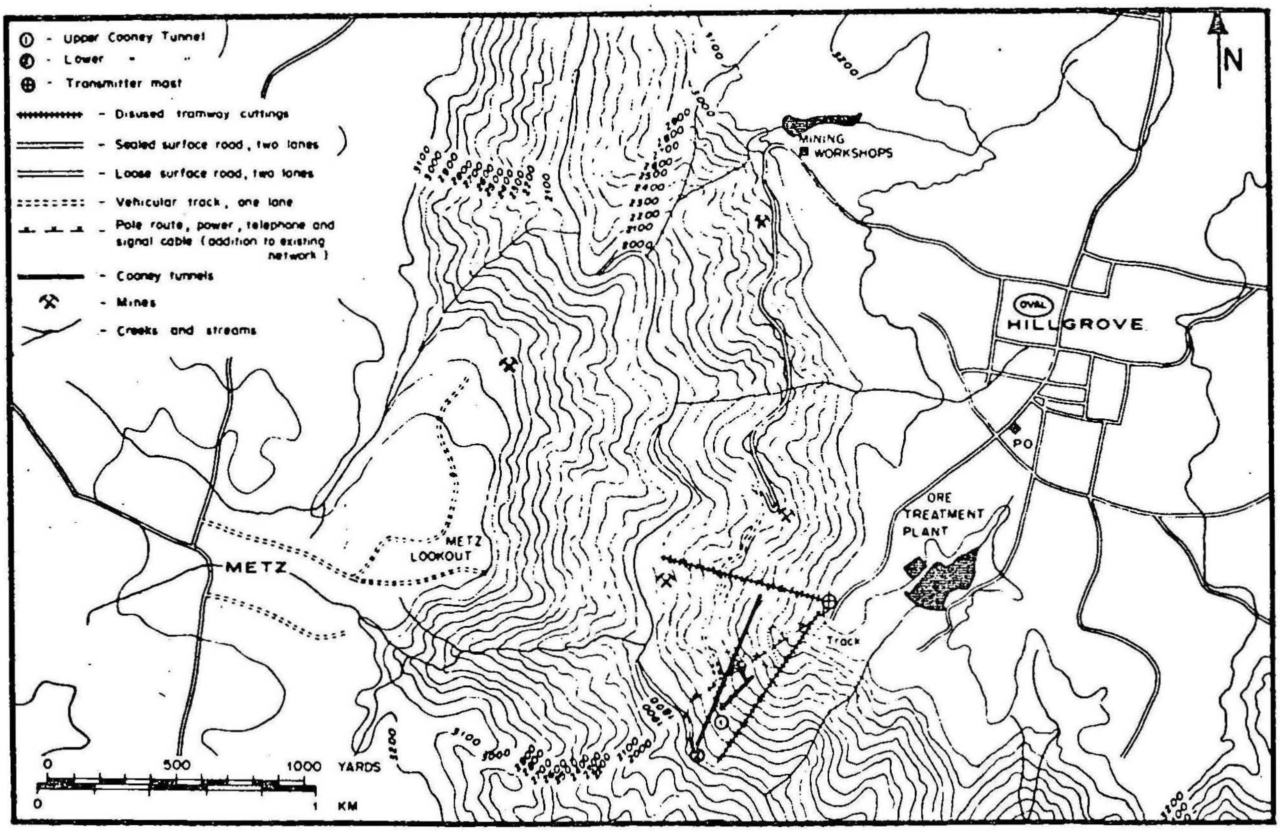

Figure 2

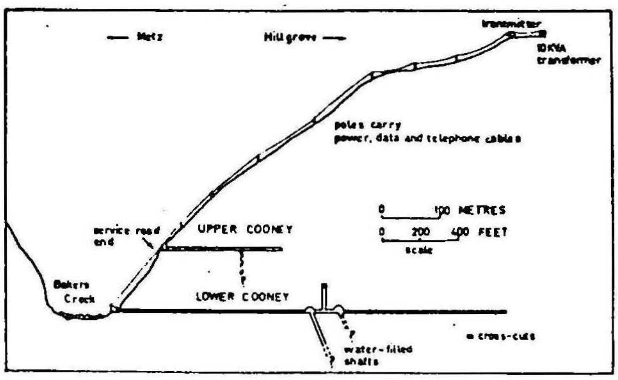

Figure 3

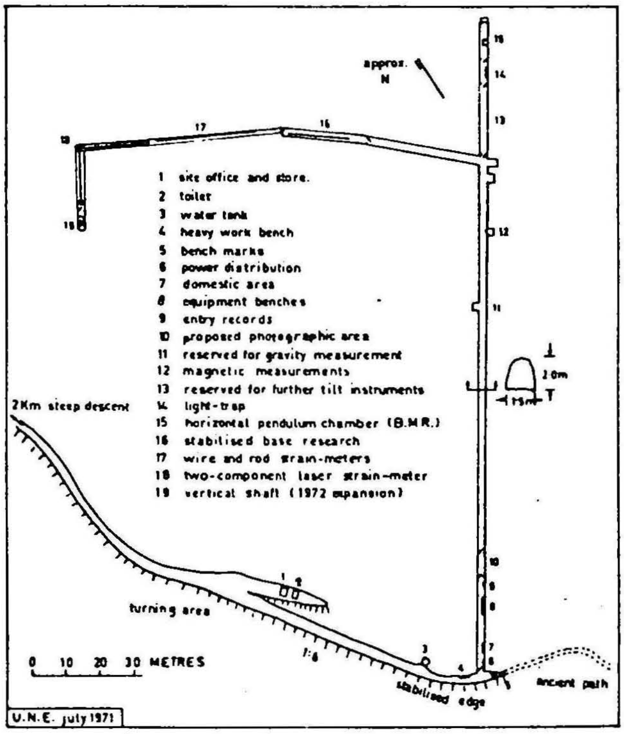

Figure 4

COONEY GEOPHYSICAL OBSERVATORY SITE, HILLGROVE, NSW.

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to ensure that each pin is a close fit in its hole and that the shape of the bottom of the pin matches the shape of the bottom of the hole. The ceiling, back, and side walls of the niche were sheathed with galvanised iron to catch and divert water entering the niche. The floor of the niche was sealed with a layer of Readibond (epoxy-resin plastic). A hinged glass door closes the front of the niche.

Moisture has been a persistent problem; fogging of the glass door of the niche was finally cured by blowing freeze-dried air on to those portions of the glass that transmit the light rays to and from the pendulum mirrors. A small amount of this dried air is allowed to weep into the niche to prevent entry of moist air from the observation chamber.

Imperfections in the pendulum mirrors, particularly that mounted on ORB 54, made sharp focusing of the traces impossible and it was necessary to re-silver these mirrors.

Automatic calibration apparatus was obtained from Melchior and installed in the observation chamber. Two of the stainless steel pins have oversized heads and support the crapaudines (expandable bearing plates) under the drift leg of each of the pendulums. The apparatus which automatically changes the height of the mercury bottle was installed close to the tunnel ceiling in order to obtain a pressure head of 1.5 m between the mercury bottle and crapaudines.

The recorders and light sources are mounted on a brick and concrete table 5 m from the niche. It was necessary to widen the tunnel at this place in order to allow access past the table to the niche. A pair of timing lights, mounted close to the niche and at the same height as the mirrors on the pendulums, provide a flash of light each hour in response to a signal from a Bulova Accutron clock.

To improve ventilation in the chamber when it is occupied for extended periods air is sucked from the ceiling of the chamber and evacuated into the main part of the tunnel by a domestic vacuum cleaner.

The portion of tunnel immediately before the observation chamber serves as a light trap and workroom. Ambient pressure is recorded in this workroom; other apparatus is being installed to record other parameters in the observation chamber, including temperatures of chamber air, niche air, rock floor of the niche, and interstitial water.

The installation commenced in August 1971 and several of the features were not installed until much later.

The records are changed weekly by UNE staff, who also make adjustments for drift as required.

AZIMUTHS AND CO-ORDINATES

The true bearing of the Upper Cooney Tunnel is $53^{\circ}13'11''$. The narrowness of the observation chamber prevents the mounting of the pendulums with the preferred N-S and E-W orientations. Tilt is measured in the mean azimuths $54^{\circ}59'$ and $142^{\circ}05'$; this limits the accuracy of determination of amplitudes and phases of the various components. The co-ordinates of the observation site are:-

Latitude (Australian National Spheroid)	$30^{\circ}34'43''$S
Longitude (Australian National Spheroid)	$151^{\circ}53'36''$E
Elevation (Australian Height Datum - mean sea level)	649.9 m

The acceleration due to gravity referred to absolute datum (IGSN 71) is 9 791 662 $\mu m/s^2$ (BMR gravity station number 7291-0646).

RECORDS OBTAINED

During the period August 1971 to July 1972 and August 1972 to June 1973 the records obtained were unsatisfactory for scaling and analysis for one or more of the following reasons:

(a) Problems due to moisture in the niche, condensation on optics etc.

(b) Extremely high drift of one or both pendulums for several months following initial installation and following later work necessary to eliminate moisture problems.

(c) Slipping clutches in the drive mechanisms of the recorder drums.

(d) Inadequate resetting of light spots during periods of medium drift.

(e) Failures of timing mechanism due to clock and relay faults.

(f) Disturbance from experimental heating rings on lenses.

(g) Failure of small refrigerator used to freeze-dry air.

During July and August 1972, a 29-day continuous set of recordings was obtained on both pendulums. No resets were made during this period as the drift rates of both pendulums were small. The records are usable but have the following defects:

(a) Poorly focused traces, particularly from ORB 54.

(b) Timing problems necessitating the use of earthquake arrival times to verify universal time datum.

(c) Incorrect setting of the calibrator arm and hence poor calibration of amplitudes.

These data were partly scaled and analysed, the principal tidal components being resolved in the records from one pendulum. The azimuths of the pendulums were not available until March 1973. By then the behaviour of the pendulums suggested that the scaled data were suspect and should be confirmed by a second set if possible.

During June and July 1973 a 37-day continuous set of recordings was obtained on both pendulums. These records are usable but have the following defects:

(a) Poorly focused traces, particularly from ORB 54.

(b) Minor problems causing intermittent faults in the drum drives and timing apparatus.

(c) High drift on ORB 53 necessitating resets about every ten days.

(d) Several periods of noise continuous over several hours or several days.

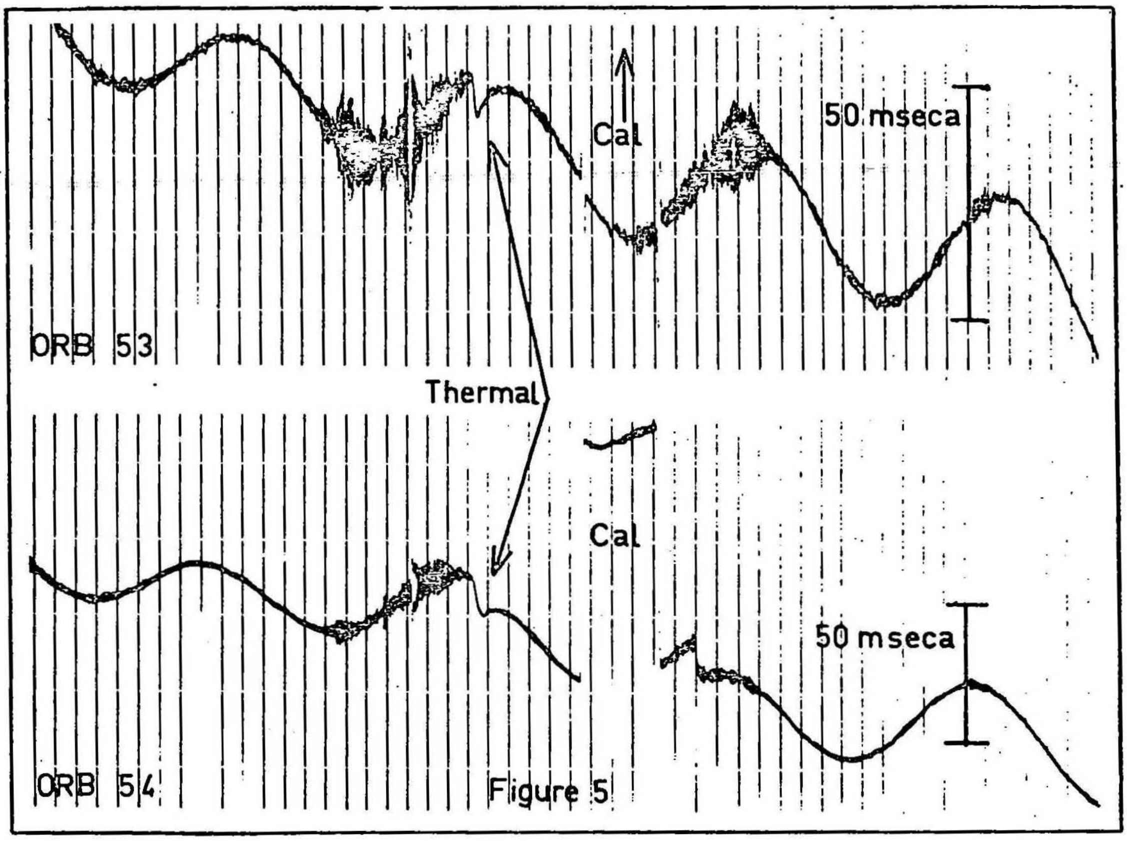

Figure 5

Explanatory notes for figures 5,6 & 7.

1. Each figure is a half-scale reproduction of simultaneous photographic records produced by the two horizontal pendulums ORB 53 and ORB 54.

2. Vertical lines are hourly time marks produced photographically.

3. The 50 mseca bar shown against each trace indicates the response of the pendulum to a tilt of 0.050 seconds of arc. During these periods of recording ORB 53 is more sensitive than ORB 54 because it is operating with a longer period.

4. Each trace includes one example of the offset produced by the auto-calibrator and crapaudine system. This offset corresponds to about 90 mseca.

5. The various figures show examples of non-tidal effects in the recent records.

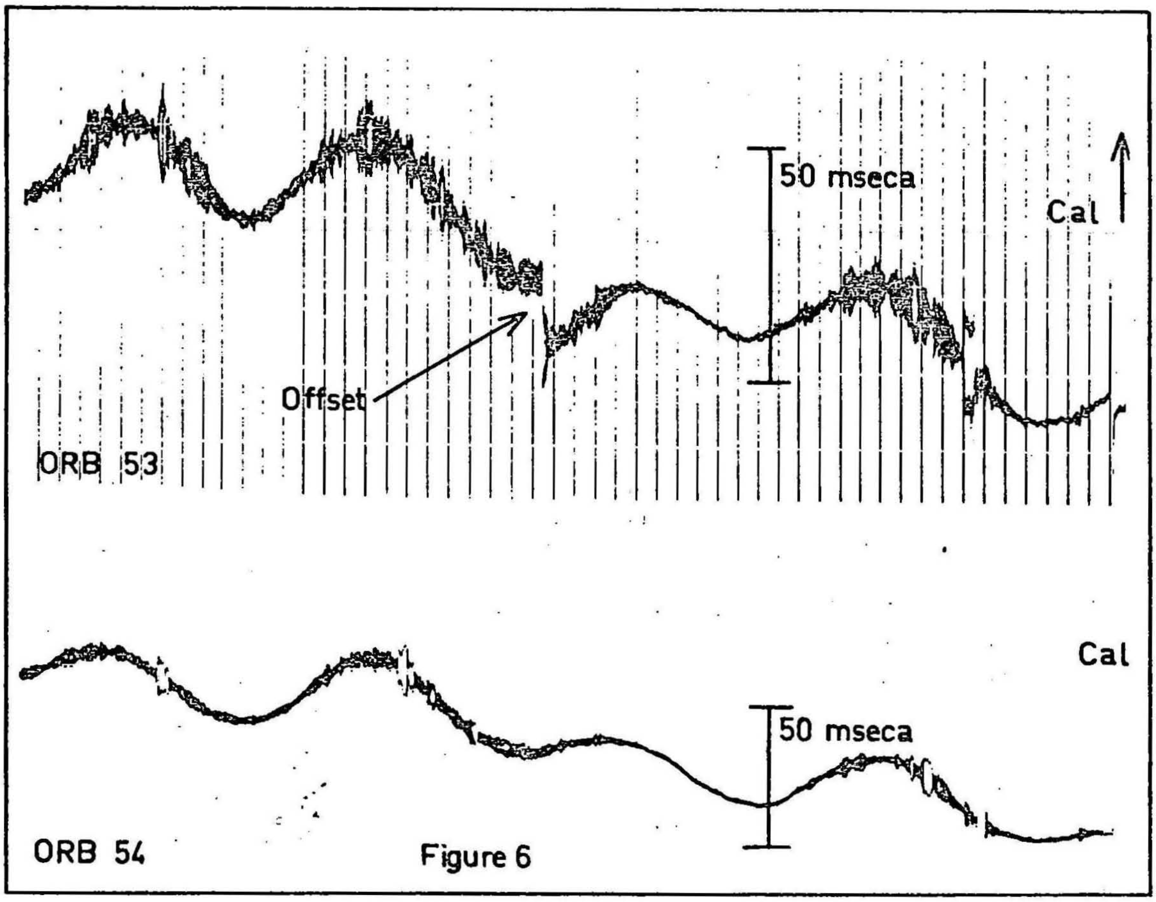

Figure 6

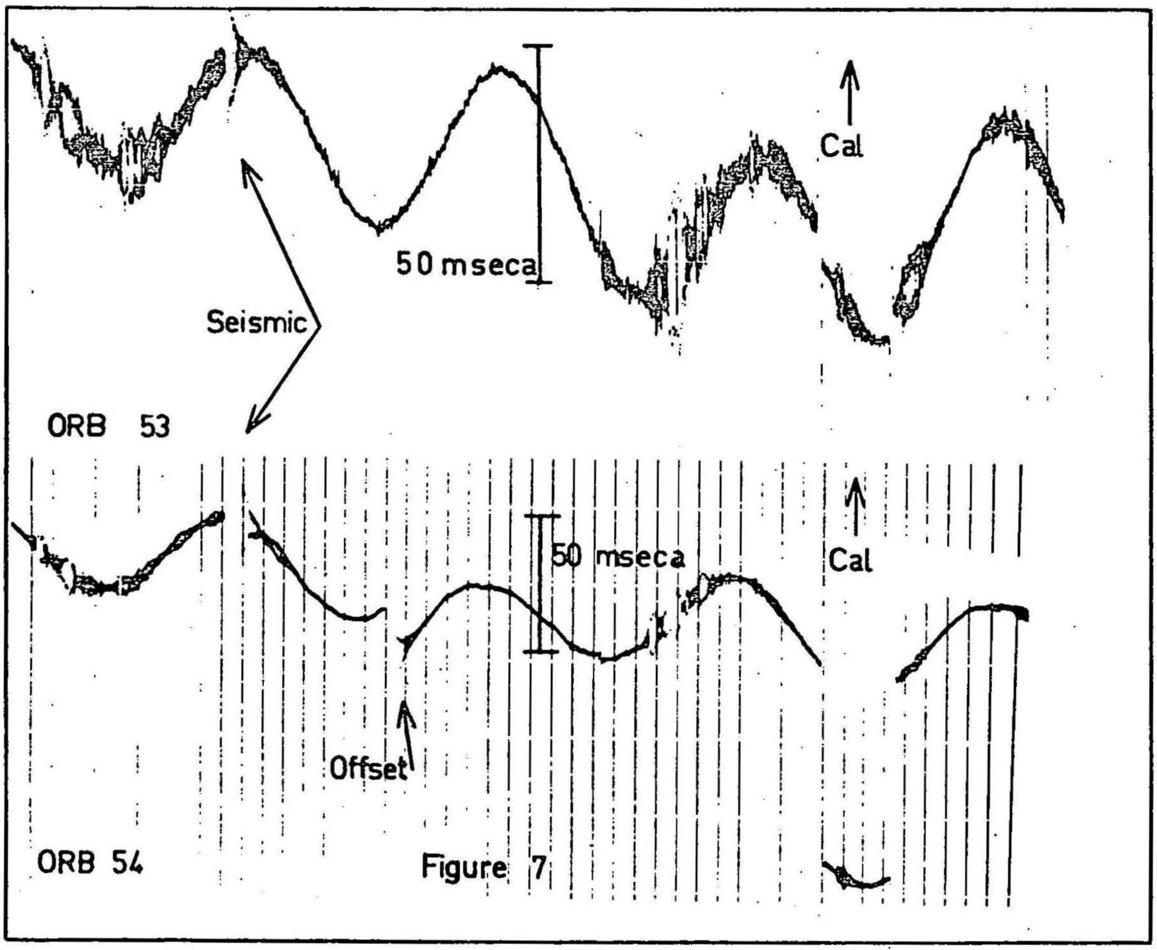

Figure 7

(e) Small tares, usually without recovery but occasionally with recovery over several hours.

The first two are instrumental faults, corrected by re-silvering the mirrors and by other repairs. The remaining faults have continued since that time. Both the noise and the tares have become more frequent, so that the June-July period data remain the best obtained to date. These records have been scaled and are being analysed at present.

The data from both sets of continuous records are being checked and re-formatted before transmittal to Brussels for detailed analysis.

NON-TIDAL EFFECTS IN THE RECORDS

Records from the pendulums show a number of interesting non-tidal effects during the 27-month recording period:

1. Drift.
2. Small tares.
3. Bays, both large and small.
4. Teleseismic and microseismic noise.
5. Discordant noise.

1. Drift

When the pendulums were first installed, both had drift rates of several hundred mseca (milliseconds of arc) per day. These drift rates fluctuated and even reversed during the first 3 months. Since then the measured drift rates have always been less than 70 and generally less than 30 mseca/day. Each pendulum has shown drift rates less than 5 mseca/day for periods of about 2 months. The drift rates of both pendulums are acceptable, although not as small as those quoted by Melchior (1966) and others.

Melchior (1966) lists several instrumental, geophysical, and tectonic effects as probable causes of drift. Movement in one of the pendulum supports, or in the fractures in the floor of the niche, was initially suspected at Cooney. The pendulums were interchanged on their supports in May 1972 in an attempt to improve focus, and were changed back again in August 1973. Thus half the recording period to date has been made with the pendulums interchanged, but the drift data do not suggest any particular effect as the probable cause of drift.

2. Small Tares

Small offsets or tares in the trace of one pendulum occur several times each week (Figs 6 and 7). They range from 1-10 mm on the record (4-40 mseca) and recovery is rarely seen to occur. Almost without exception, these tares occur in the trace of only one pendulum and are in the direction of the apparent drift. It follows that their cause is instrumental and lies in the pendulum apparatus or in the support pins. It is possible that the observed drift is mainly or totally due to the accumulated effect of such tares.

3. Bays, Both Large and Small

Large bays, during which the trace is displaced 20-400 mm, are rare. Both pendulums are affected and recovery appears to be complete. The shape of the trace is similar to that recorded after the environment has been thermally disturbed, the displacement occurring over 5-20 hours. These bays are thought to be due to thermal effects. Smaller bays of 5-20 mm amplitude and lasting ½ - 2 hours occur every few months. These bays also are thought to be thermal in origin (Fig. 5).

4. Teleseismic and Microseismic Noise

Distant earthquakes, local tremors, rock-bursts, and man-made explosions contribute noise to the records (Figs 5, 6 and 7). Individual arrivals of energy occur simultaneously on the traces of both pendulums. The noise level is frequently high during normal working hours, even though the observatory itself is unattended. It is likely that this daytime noise is generated by mining activity in the area. Although no mines are worked within 1 km of the site, ore is treated in a plant on the hill above the observatory. Several periods of unexplained noise have continued without break for periods of 2-6 days.

5. Discordant Noise

Discordant noise affects one pendulum only, or affects both pendulums over a period with different arrival times for individual energy packets. Time differences of 10-40 minutes are observed. No explanation for this noise has been found.

NEED FOR FURTHER WORK

Several recent papers have indicated that a niche excavated in the end wall of a tunnel is not an ideal site for the recording of tidal tilt because of unequal stress relief parallel and transverse to the axis of the tunnel. Moreover the present site does not permit the pendulums to be oriented north-south and east-west. A better site may be found in the centre of one of the large chambers of Lower Cooney, but is likely to have the same noise level as the present site.

Lennon and Baker (1973) discuss the discrepancies in the tilt attenuation factors and phases reported by the various earth tide stations in Central Europe. Tilt records from a number of stations yet to be established throughout Australia are required, but there is so little activity in this field (Sydenham, 1973) that it is impossible to forecast when these data will be available.

The analysis of tilt data from the present site will be of interest because it will be first data from this part of the globe. Nevertheless it should be treated with reserve until joined by data from other sites. It is impossible to distinguish between regional and global influences in the data from only one site.

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