A DIGITISED VERSION OF C. B. WATTS' CHARTS
OF THE MARGINAL ZONE OF THE MOON

L. V. MORRISON and R. J. MARTIN

HM Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle,
Hailsham, Sussex, U.K.

(Received 28 December, 1970)

Abstract. C. B. Watts' charts of the marginal zone of the Moon have been put into the form of
tables of rectangular co-ordinates of points along the contours. These co-ordinates were recorded
automatically on paper tape and transferred, firstly to a magnetic tape, then secondly to an exchange-
able-disc cartridge allowing random access to every chart.

1. Introduction

In 1963 Watts published 1800 charts giving the apparent angular heights above and
below a mean spherical datum surface for physical features on the Moon's limb at
nearly all librations. There is a chart for every 0\degree 2 of position angle from the Moon's
axis. The charts for 40\degree 0 and 269\degree 4 are shown in Figure 1. The horizontal and vertical
scales are the topocentric libration in longitude and latitude, respectively, in degrees.
The contour heights, continuous for above and broken for below the mean surface,
are in units of 0'1 and at an interval of 0'2 usually allowing a visual read-off precision
of better than 0'05 when interpolating to some specific point.

These charts are used in HM Nautical Almanac Office for determining the values
of limb corrections to be applied in the reduction of the timing of occultations of
stars by the Moon. The application of limb corrections refers the observations to the
centre of Watts' datum surface. The position of this centre is compared with the
ephemeris of the centre of the Moon to determine various corrections to lunar theory
and the fundamental star system.

About 40000 observations of occultations have been collected since 1943 for use
in a detailed analysis now in progress. The determination of the limb corrections by
visual interpolation of the charts is laborious and time consuming and so it was
decided to reduce the charts to a machine-readable form for automatic processing
by a computer. This article explains how this was done by using a 'D-mac Pencil
Follower'.

2. Equipment and Method

A. D-MAV PENCIL FOLLOWER

This machine consists of a table on which the graphical material to be digitised is
placed. A gantry mounted beneath its surface accurately follows the coil in the
Reading Pencil unit, used to follow the graph, by inductive coupling. The position
of the gantry in a rectangular coordinate system \((X, Y)\) is registered and punched on
paper tape when a switch on the 'pencil', or a foot-switch, is pressed. The position
of the centre of the pencil head on the table surface is registered with an accuracy of 0.1 mm. Auxiliary information can be added to the tape using a keyboard.

B. TRACING PRECISION REQUIRED

Watts (1962) had estimated the accuracy of his charts to be \( \pm 0.1 \) and use in HM Nautical Almanac Office has suggested that the accuracy is not better than this. It was decided that the precision of the tracing should be such as to allow an accuracy of no worse than \( \pm 0.1 \) to be obtained from the digitised version. The closest contours on the charts are spaced about 1 mm apart, so that 0.1 mm corresponds to a height change of 0.02. This was better than the required accuracy provided that extra care was taken in tracing these close contours.

C. TRACING PROCEDURE

Each chart was fixed on the D-mac table with its axes approximately parallel to the edge of the table. The position of the chart was key-punched on to the paper-tape and the positions of the four corners were recorded clockwise from the top left to provide the scale and orientation of the chart. For each contour in turn the operator first key-punched the height and then traced it, taking a reading at the beginning of the line and at points along the line until the end, such that straight lines connecting the points would describe the curve of the contour with adequate precision. By restricting the frequency of readings in this way it was possible to obtain an adequate representation of the charts and yet keep the total number of readings to about 1 million, which is within the storage capacity of a single exchangeable-disc cartridge of the type in use on the ICL 1909 computer.

To simplify the interpolation program to be used with the charts, unclosed odd-valued 'contours' were added by inspection along 'ridges' and 'valleys' wherever this appeared to be necessary to allow linear interpolation to be used without introducing errors greater than 0.1; for example, the lines headed '3' in chart 40°0 of Figure 1. A user not requiring these added contours can simply remove them by testing for odd-valued headings.

D. FORMAT OF DATA

Each record consisted of 8 numerical characters, and normally represented one position, i.e. a pair of unsigned X- and Y-coordinates in units of 0.1 mm. A zero value of the X-coordinate indicated a special record as follows; for the first record, the Y-value indicated the position angle of the chart in units of 0.1 (always followed by the positions of the four corners of the chart), thereafter, the Y-values indicated the heights, in units of 0.1, of the intervening positions taken along the contours. A value of 9999 for \( Y \) indicated the end of the chart, and a value of 9999 for \( X \), the end of the tape.

E. TRANSFERRING AND CHECKING OF PAPER-TAPE DATA

The paper-tape data for groups of five charts (one degree of position angle) were