COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/24

BROKEN HILL AIRBORNE MAGNETIC AND RADIOMETRIC SURVEY, NSW 1957-59.

by

A.G. Spence

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SUMMARY

Airborne surveys were made by the Bureau of Mineral Resources in the Broken Hill district during 1957 and 1959 using magnetometers and scintillographs. Some correlation between magnetic features and regional geological structure is indicated.

Forty-one radioactive occurrences were also detected. These should serve as a guide in any further prospecting for radioactive minerals in this area.

1. INTRODUCTION

This Record describes the airborne surveys conducted by the Bureau of Mineral Resources in the Broken Hill area, New South Wales during 1957 and 1959. The Bureau had previously conducted airborne surveys in this region in 1954 and 1955, primarily as part of its programme of uranium search. The 1954 survey was a detailed magnetometer and scintillograph survey of the mining district. In 1957 this survey was extended to the north and north-east. Some technical difficulties were encountered in tying-in the 1954 magnetic results with those of the 1957 survey. To resolve these difficulties it was considered desirable to re-fly the 1954 survey area and this was done in 1959.

The areas covered by the 1957 and 1959 surveys are shown in Plate 2. The total area was approximately 2000 square miles. DC3 aircraft owned by the Bureau were used in each survey, VH-BUR in 1957 and VH-MIN in 1959.

The 1957 party comprised A.G. Spence (party leader), F. Jewell, R.M. Carter, M. Kirton, P. Gillespie, D. Upton, W. Spence, M. Hazelbrook, P. Grimsley, F.G. Walker, C. Braybrook, and R. Jones, all of the Bureau of Mineral Resources, and L. Evans, D. Wright, and F. Macdonald of Trans-Australia Airlines. The 1959 party comprised A.G. Spence (party leader), R. Wells, and C. Braybrook of the Bureau of Mineral Resources, and N.K. Pascoe, G.C. Greene and W. Briggs of Trans-Australia Airlines.

2. METHOD

The variations in total magnetic intensity and in gamma radiation were systematically recorded throughout the area with an airborne magnetometer and scintillographs respectively.

In the northern area the navigation of the aircraft along flight-lines spaced 0.2 miles apart and the plotting of its position were done using a Shoran radio location system. In the southern area, aerial photos were used for navigation along flight-lines spaced 0.25 miles apart; 35-mm vertical strip film was used in plotting the aircraft's position. The height of the aircraft was maintained at 500 ft ($\pm$ 100 ft) above ground level.

Tie-lines were flown to provide the information required to reduce the results along individual flight-lines to a common datum.

3. EQUIPMENT

Saturable core fluxgate magnetometer, type MFS-4, were used on both surveys. The detector head in each installation was mounted in a boom projecting from the tail so as to remove it as far as possible from the disturbing fields of the aircraft's own magnetism. The output was recorded on a Speedomax recorder in each case.

Two separate scintillographs were carried in each aircraft. One was mounted in the aircraft and consisted of two MEL detectors, the combined outputs of which were fed into a BMR-type ratemeter and recorded on one channel of a dual-channel Recti-riter recorder. The other scintillograph measured the radiation level at a height that was about 300 ft below the aircraft. The detector in this case was contained in a 'bird' which was towed by the aircraft on 500 ft of cable. The output of this detector was fed into an MEL ratemeter and recorded on the second channel of the dual-channel recorder.

The altitude of the aircraft was continuously measured and recorded by an STR30B radio-altimeter. The altitude profile so recorded was used for correcting the radiometric data.

The Shoran radio navigation system consisted of an AN/APN-84 set installed in the aircraft and three AN/CPN-2A ground stations. The aircraft set was operated simultaneously with two ground stations to give a continuous triangulation fix of the aircraft's position. The ground stations were located on sites chosen to give line-of-sight coverage over the area being surveyed and as far as possible were established on surveyed trig stations. The distances between aircraft and ground stations were continuously displayed on two sets of mileage counters. One set was used by the pilots in navigating the aircraft and the other was photographed every 10 sec to provide data for plotting the aircraft's track.

In the photo-navigated area an air-position indicator was used to record the air position of the aircraft. This plot was subsequently used in conjunction with the vertical strip film to assist the plotting of the flight-lines.

A fiducial marker system was employed to correlate the chart and film records.

4. GEOLOGY

The following brief notes are based on King and Thomson (1953). Plate III which accompanies their report represents the most comprehensive mapping of the geology of the Broken Hill district published to date.

The rocks are almost entirely Precambrian of two ages, the older Willyama Series and the younger Torrowangee Series. The former occurs in a roughly triangular block 70 miles in a northerly direction by 40 miles across the base and in an inlier to the north-east (Euriowie Inlier) about 50 miles long by 7 miles wide. The Willyama and Torrowangee Series are separated by an unconformity.

The Willyama Series consisted originally of thin bedded argillaceous and arenaceous sediments, probably of Archaean age, which were converted by regional metamorphism over most of the area into sillimanite-biotite-garnet gneiss, and into sericite, andalusite, and staurolite schist. In the extreme northern portion of the area, the sediments are slightly metamorphosed and resemble Torrowangee sediments. In the Willyama Series, there is a variety of igneous rocks and metamorphic/metasomatic rocks - granitic gneiss, granulite, aplite, amphibolite, serpentine and hornblendite, dolerite dykes, granite bosses, and pegmatite. Stratigraphic correlations of the Broken Hill district have been based mainly on certain distinctive rock types such as granitic gneiss, aplite, garnet-magnetite and quartz-magnetite horizons, and amphibolites.

The Torrowangee Series appears to be the equivalent of the Mitcham, Sturtian, and Brighton stages of the upper series of the Adelaide System. The sediments consist of tillite and glacial boulder beds, with quartzite and conglomerate close to the base of the Series. The next rock type in the succession is flaggy sandstone with shale and glacial erratics, followed by limestone with shale and glacial erratics, cleaved shale or claystone with tillite, and claystone with quartzite. The constituent rocks of the basal quartzite are sedimentary in origin and are tightly folded within underlying schist. This folding is presumably related to the overthrusting of Torrowangee sediments against the Willyama basement. Silicification has taken place in the zone of overthrust.

The Willyama Series has been intensely deformed along north-easterly axes. Folding in the mining area is deep and isoclinal, and most anticlinal structures are tightly sheared, whereas the synclines tend to be broad and open with well-rounded noses. The main Broken Hill lodes occur on one of these anticlinal structures, referred to as the Broken Hill Anticline.

Subsequent to the folding, major faults were developed in three principal directions. All of these faults are crush-zones, mostly marked by wide zones of schist. The most outstanding of these features are probably the Vauxhall Crush Zone and the Thackaringa Fault. The Torrowangee Series, separated from the Willyama Series by an unconformity, has been deformed into a succession of gentle flat-pitching folds with axes trending north to north-west.

5. RESULTS

The aeromagnetic map may be divided into several zones on the basis of the character of the observed magnetic patterns.

A central zone extending from the south-western corner north-eastward to Yanco Glen (Plate 2) is characterised by many isolated intense anomalies of circular to elongated form, superimposed on a pattern of moderate magnetic activity. This zone roughly corresponds with that of 'high-grade' metamorphism referred to in geological reports of the district. Many of the anomalies can be correlated with outcrops of amphibolite or quartz-magnetite.

The area north of Yanco Glen is only slightly magnetically disturbed over pegmatite and sillimanite rocks of the Willyama Series, outcrops of Torrowangee sediments, and unmapped portions of the Euriowie Inlier. Low-intensity anomalies are characteristically developed over granite outcrops around Gairdners Tank. There is a distinct lack of the intense elongated anomalies recorded in the previously described area. Groups of small circular anomalies are often associated with isolated amphibolite outcrops.

Two distinct zones of magnetic activity are indicated, one north of Thackaringa and the other south and east of Balaclava. Here the magnetic pattern is highly contorted in a maze of intense anomaly forms. Generally these anomalies resemble in shape and intensity the isolated anomalies in the central band south-west of Silverdale, but show none of the north-east elongation of the major anomalies surrounding the city of Broken Hill. It is not possible at this stage to correlate these zones of intense magnetic activity with particular rock outcrops because they occur in sand-covered areas on the flanks of the Barrier Range. The anomalies obviously originate from magnetite-rich rocks, and it is not unreasonable to ascribe their source to quartz-magnetite and amphibolite which are correlated with intense anomalies in other parts of the district. The zones are separated from the central metamorphic zone by distinct magnetic gradients near Thackaringa and Balaclava, the intensity of which suggests sharp contacts of considerable depth extent between the weakly magnetic acidic rocks of the central zone and the strongly magnetic basic rocks of the outer zones. The problem of the nature of these basic rocks and their iron-rich origin in the pre-metamorphic history of this area requires particular attention in any future study of the petrogenesis of the Broken Hill district.

Correlation of magnetic pattern with known structure

The following observations were made in an attempt to correlate some of the major structures in the Broken Hill area with the magnetic results. Plate 1 shows the major structures and is reproduced from Figure 7 of King and Thomson (1953).

Broken Hill Anticline. A line of elongated magnetic anomalies appears to correspond closely with the Anticline. The line trends in a north-easterly direction from about two miles south of Broken Hill and can be followed through to a point about two miles south-west of Mount Gipps. The anomalies are probably due to the garnet-magnetite-quartzite horizon (banded iron formation) which is an important marker bed in this and other anticlines in the Broken Hill district.

Broken Hill Basin. This is a broad syncline, the axis of which extends from about one mile east of White Leads to the vicinity of the Flying Doctor base. The contour map shows a magnetic anomaly which commences one mile east of Broken Hill, strikes east across the northern part of the Basin then turns to the south along the eastern boundary of the southern half of the Basin. Surface geological mapping shows amphibolite in the east-west arm of this anomaly whereas its southern extension is covered by alluvium. There appears to be no known structure corresponding to this anomaly.

Rupee Anticline and Darling Range Basin. This anticline lies on the eastern side of the Broken Hill Anticline and passes through Thorndale and Rupee. The Darling Range Basin is a complex syncline lying about two miles south-east of, and parallel to, the Rupee Anticline. A broad complex magnetic anomaly runs parallel with both these structures but its relation to the structures is obscure. Its western edge corresponds fairly closely to a known banded iron formation and it covers an area in which amphibolite crops out extensively.

Laurel Anticline. This complex anticlinal feature extends from near Balaclava Tank eastward to the old Laurel workings, thence north-eastward to the vicinity of the Rockwell Hotel. There is no well-defined magnetic anomaly corresponding to this feature. However, the general trend of the magnetic pattern conforms to that of the observed structure and a fairly-well-defined anomaly lies parallel to the Anticline and south of it.

Hanging Wall Basin. Hanging Wall Basin lies to the west of the Broken Hill Anticline and is indicated by a magnetic 'low' bounded on the west by an anomaly that runs parallel to the Broken Hill Anticline for some distance.

Prominent lines of anomalies indicative of structure are also recorded north-west of Stirlingvale, north-east of Thackaringa, west of Acaciavale, and near Nine Mile. Quartz-magnetite deposits near Lindsays Creek are associated with well-defined anomalies.

Faults and contacts

Generally the faulting is not clearly indicated by the magnetic pattern, particularly in the case of faults that are parallel to the strike of the country rock.

Some expression of the Thackaringa Fault is to be found in the magnetic contour pattern but it would be difficult to infer its existence from magnetic evidence alone. Evidence of the East-west Fault, Sentinel Fault, and Stephens Creek Fault also appears on the contour map.

On the north-western boundary of the Willyama block, the Mundi-Mundi Fault is reflected in the trend of the anomalies intersected by the Mundi-Mundi Creek and the Little Aller and Big Aller Creeks. The anomalies on the western side of the fault are broader and have somewhat lower gradients than those on the eastern side.

Along the north-eastern edge of the Euriowie Inlier there is a bending of successive contours in a south-eastern direction along a line conforming to the boundary of the Inlier. Similarly the north-eastern edge of the main Willyama block is marked by a line of anomalies through Thompsons Tank. It will be noticed that the magnetic pattern over Torrowangee sediments east and west of the Euriowie Inlier is unmarked by intense anomalies.

Radiometric results

Forty-one positions are indicated on the map where the radioactive intensity is substantially greater than the average intensity in the surrounding area.

The occurrences do not appear to correlate with the geology, except that generally the Torrowangee Series is less radioactive than the Willyama Series.

6. CONCLUSIONS

There is some correlation between patterns in the aeromagnetic map and known geological structure in the Broken Hill district. The map also indicates the existence and trend of structures not revealed by geological surface mapping.

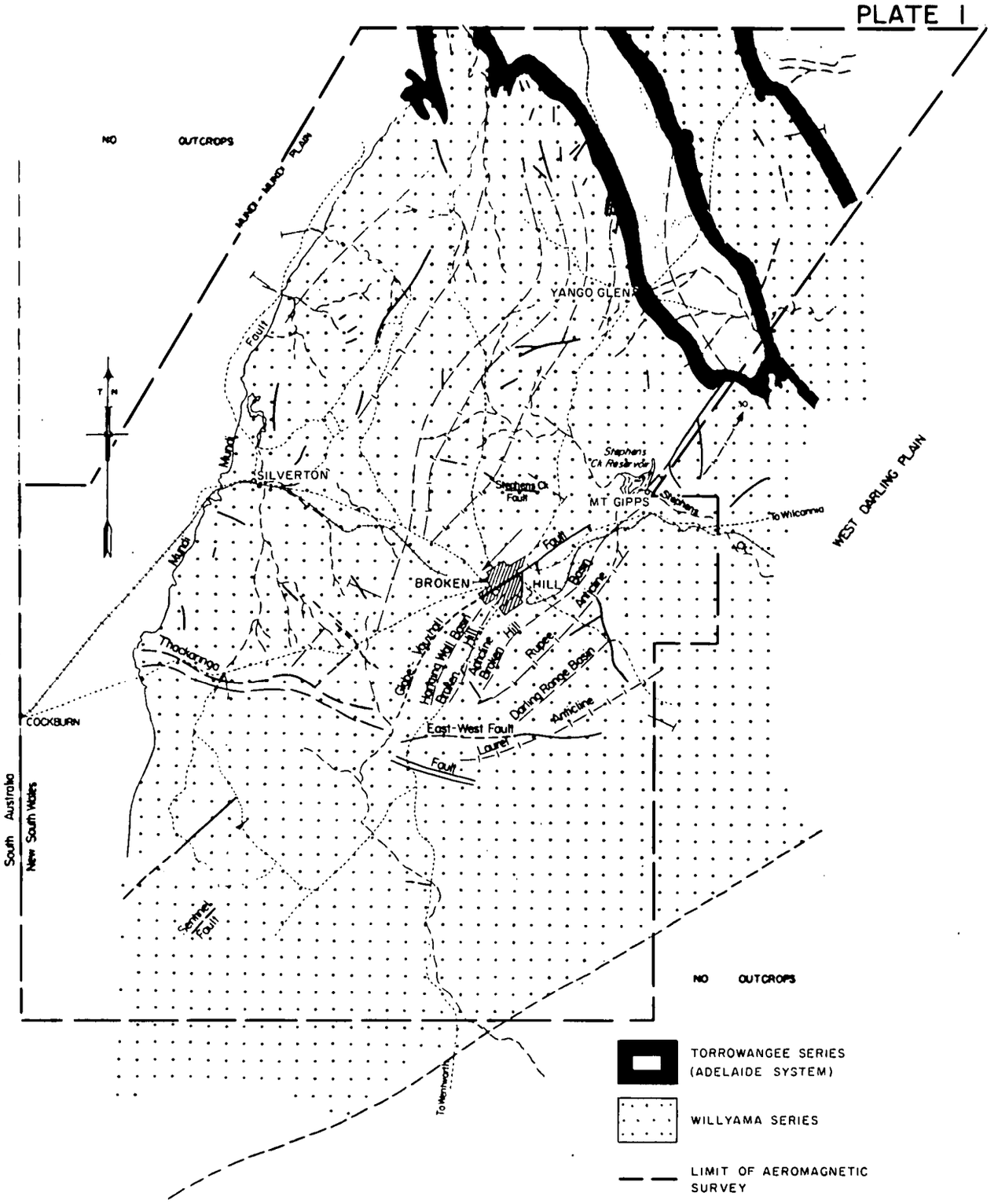
The source of the aeromagnetic anomalies appears to be confined largely to two rock types, amphibolite and quartz-magnetite. These rocks recur as important marker beds in the stratigraphy of the Willyama beds; this fact may make the magnetic map useful in future assessments of the stratigraphic sequence in the various geological structures of the district.

The aeromagnetic map has clearly indicated two large zones of magnetite-rich rocks on the eastern and western borders of the area termed as one of high-grade metamorphism. The pre-metamorphic origin of these iron-rich rocks (possibly amphibolite) is a problem to be solved in determining the petrogenesis of the mining district.

7. REFERENCE

KING, H.F. and THOMSON, B.P. 1953 The geology of Broken Hill district. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 5th Emp. Min. Metall. Congr. 1, 533-577, Melbourne, AIMM.

PLATE 1



BROKEN HILL AREA

MAJOR GEOLOGICAL STRUCTURES

(AFTER KING AND THOMSON, 1953)

SCALE

MILES 10 0 10 MILES

H54/B1-2

TO ACCOMPANY RECORD No. 1963/24

BROKEN HILL AREA, N S W

MAP SHOWING

TOTAL MAGNETIC INTENSITY

MEASURED BY AIRBORNE MAGNETOMETER

AND

RADIOACTIVE ANOMALIES

DETECTED BY AIRBORNE SCINTILLOGRAPH

SCALE

MILES 2 1 0 2 4 6 8 10 MILES

KILOMETRES 5 0 5 10 KILOMETRES

MAGNETIC CONTOUR INTERVAL 50 GAMMAS

MAP DATA

PROJECTION : TRANSVERSE MERCATOR, AUSTRALIAN SERIES.

CONTROL & DETAIL : PLANIMETRIC DETAIL WAS REDUCED FROM PHOTO SCALE MAPS COMPILED BY DIVISION OF NATIONAL MAPPING, DEPARTMENT OF NATIONAL DEVELOPMENT. CO-ORDINATE VALUES ARE BASED ON THE GEOGRAPHICAL CO-ORDINATES OF SYDNEY OBSERVATORY.

RELIABILITY : PLANIMETRIC DETAIL; ACCURATE. GEOPHYSICAL DATA; RELIABILITY OF PLOTTED POSITION OF AIRCRAFT, WITHIN ± 75 YARDS.

LEGEND

TOPOGRAPHICAL DATA

- RIVER OR CREEK
- MAIN ROAD
- ROAD OR TRACK
- RAILWAY
- FENCE
- NAMED PLACE
- HOMESTEAD
- TANK
- MINE
- AERODROME

MAGNETIC DATA

- MAGNETIC CONTOURS
- MAGNETIC LOW

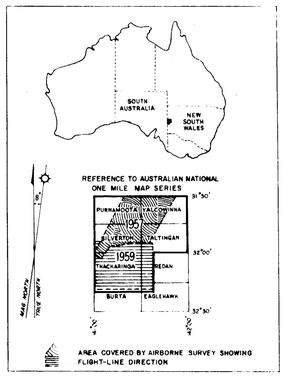
SCINTILLOGRAPH DATA

- ANOMALY

GEOLOGICAL DATA

- TORROWANGEE SERIES (ADELAIDE SYSTEM)
- WILLYAMA SERIES

LOCATION DIAGRAM



EXPLANATORY NOTES

THIS MAP WAS COMPILED FROM AIRBORNE SURVEYS OF THE BROKEN HILL AREA CONDUCTED BY THE BUREAU OF MINERAL RESOURCES IN 1957 AND 1959. THE OBJECTS OF THE SURVEYS WERE (A) TO DELINEATE MAGNETIC ANOMALIES WHICH MIGHT BE ASSOCIATED WITH MINERAL DEPOSITS OR REVEAL STRUCTURAL TRENDS IN THE GEOLOGY OF THE AREA AND (B) TO INDICATE AREAS IN WHICH URANIUM MINERALS MIGHT OCCUR.

THE AREA WAS SURVEYED WITH A D.C.3 AIRCRAFT FLOWN AT AN ALTITUDE OF 500 FEET ABOVE GROUND LEVEL. THE HEIGHT OF THE AIRCRAFT WAS CONTROLLED THROUGH A RADIO ALTIMETER. IN THE 1957 SURVEY, FLIGHT-LINES WERE SPACED ONE FIFTH OF A MILE APART AND THE POSITION OF THE AIRCRAFT WAS DETERMINED BY A SHORAN RADIO NAVIGATIONAL SYSTEM. IN THE 1959 SURVEY, AERIAL PHOTOGRAPHS WERE USED FOR NAVIGATION ALONG FLIGHT-LINES SPACED ONE QUARTER OF A MILE APART. THE ACTUAL COURSE OF THE AIRCRAFT WAS RECORDED BY A 35-MM VERTICAL CAMERA OPERATED DURING FLIGHT.

THE TOTAL MAGNETIC INTENSITY WAS RECORDED CONTINUOUSLY BY AN AIRBORNE MAGNETOMETER. THE DATA REMAIN UNCORRECTED FOR A REGIONAL GRADIENT IN TOTAL MAGNETIC FIELD OF 9·0 GAMMAS PER MILE IN A DIRECTION 3·8°W.

THE GAMMA RADIATION FROM THE GROUND WAS RECORDED CONTINUOUSLY ALONG FLIGHT-LINES BY AN AIRBORNE SCINTILLOGRAPH. ANOMALIES MARKED ON THE MAP INDICATE WHERE THE RADIOACTIVE INTENSITY WAS SUBSTANTIALLY GREATER THAN THE AVERAGE INTENSITY OF THE SURROUNDING AREA. NO CLAIM IS MADE THAT THE ANOMALIES CORRESPOND TO URANIUM DEPOSITS. INVESTIGATION ON THE GROUND IS NECESSARY TO DETERMINE THE SIGNIFICANCE OF THE ANOMALIES.

NOTE : THIS MAP SUPERSEDES 6135-11 AND 6269-7.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, DEPARTMENT OF NATIONAL DEVELOPMENT.

H54/BI-3

TO ACCOMPANY RECORD No. 1963/24