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Meteorites from the Nullarbor Region, Western Australia: I. A review of past recoveries and a procedure for naming new finds

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Abstract—Currently, 44 distinct meteorites are recorded from the Nullarbor Region in Western Australia. Recovery data for the Billygoat Donga, Cardanumbi, Cocklebiddy, Forrest Lakes, Laundry East, Lookout Hill, North East Reid, North Reid, Reid, Webb, West Forrest, West Reid and Yayjinna meteorites are amended, and North Forrest is recognized as distinct from North West Forrest (H).

Since 1971, the recovery of more than 500 specimens (predominantly ordinary chondrites) from the desert has made the Nullarbor Region one of the most productive areas of the world for meteorite recoveries and has caused major problems for meteorite nomenclature. To overcome a lack of geographical names, we have delineated a grid of 47 named 'areas' in the Nullarbor Region. Henceforth, distinct meteorites will take the name of the 'area' in which they are found and a number (*e.g.,* 001) in order of discovery. In general, the names of past recoveries remain unchanged. The absence of transportation processes in the region, and accurate documentation of the distribution of finds allows 'pairing' of specimens to at least 90% level of confidence.

INTRODUCTION

THE NULLARBOR REGION IS an area of generally treeless, limestone desert, situated in the south of the Australian continent. The region forms part of a larger, but geologically and physiographically similar area known as the 'Eucla Basin' (Lowry, 1970) which straddles the border between South Australia and Western Australia (Fig. 1).

The semi-arid to arid climate of the region, conducive to the preservation of meteoritic materials, combined with a general lack of vegetation and pale country rock has made the Nullarbor Region an ideal spotting ground for meteorite finds. To date, 44 distinct and well documented meteorite finds are recorded from that portion of the Eucla Basin in Western Australia, comprising three irons, one stony-iron, thirty-seven chondrites, one eucrite and two ureilite achondrites (Table 1). In addition, since 1971 a large number (>500) of individuals and fragments of meteorites (predominantly ordinary chondrites) have been recovered from the Eucla Basin in Western Australia and deposited at the Western Australian Museum. Most of this new material has not been described and the total number of distinct meteorite falls represented has yet to be determined. Excluding Antarctica, the Nullarbor Region is one of the most productive areas of the world for the recovery of meteorites.

Owing to the generally featureless nature of the region and the consequent scarcity of geographical names, nomenclature has always been a major problem associated with the description of Nullarbor meteorites. In the past (*e.g.,* McCall and Cleverly, 1970), the problem of naming meteorites has been dealt with in three main ways: (a) by appending a directional term to the few existing geographical names, *e.g.,* North Reid; (b) by inventing unofficial locality names, *e.g.,* Dingo Pup Donga, and (c) by a combination of (a) and (b), *e.g.,* Mulga (north). All of these methods of naming contradict the general guidelines on meteorite nomenclature and are potentially confusing.

More recently, in line with item 3.3 of the *Guidelines For Meteorite Nomenclature* (1980), parenthesized lower case letters have been added to distinct finds from the same locality, *e.g.,* Forrest (a) and Forrest (b). In general, the numbers of distinct meteorites recovered from most Nullarbor localities do not yet exceed the number of letters in the alphabet. However, the large number of recent finds (Bevan and Binns, 1989), many from the sites of previously documented but distinct meteorites, demonstrates that the problem of Nullarbor nomenclature is cumulative, and that the discovery of many more meteorites can be expected in future. In addition, there is the strong possibility that many specimens belong to the same fall or shower. In the case of meteorite finds from the Nullarbor Region, the complexities of 'pairing' render the conventional system of nomenclature unworkable.

The purpose of this paper, the first of a series on Nullarbor meteorites, is to review past recoveries and outline a system of nomenclature designed to provide a consistent, lasting but flexible framework for the description of new meteorite recoveries from the Nullarbor Region. The scheme has been approved by the Meteorite Advisory Committee of Western Australia and by the Meteorite Nomenclature Committee of the Meteoritical Society.

THE EUCLA BASIN, NULLARBOR REGION AND PLAINS

In Western Australia, the Eucla Basin covers an area of about 104,000 sq km and has been divided by Lowry (1970) and Beard (1975) into a number of recognizable physiographic regions (Fig. 2). The main physiographic region, alternately known as the 'Bunda Plateau' or 'Nullarbor Region,' covers an area of approximately 100 000 km² and is essentially featureless. This plateau, which is formed on flat-lying limestone of Early Miocene age, slopes gently southward from an altitude of 240 m at its northern margin where it is encroached upon by sand dunes of the Great Victoria Desert, to about 90 m in the south where it is truncated by an erosion scarp, the Hampton Range, which represents a former coastline of the Great Australian Bight (Fig. 2). The Nullarbor Region is sub-divided by Lowry (1970) and Beard (1975) into five main physiographic units differing subtly in vegetation, climate and geology. These units are called the Carlisle Plain, Nyanga Plain, Mardabilla Plain, Hampton Tableland and Nullarbor Plain *sensu stricto* (Fig. 2). In addition, situated between the Nullarbor Region and the present coastline

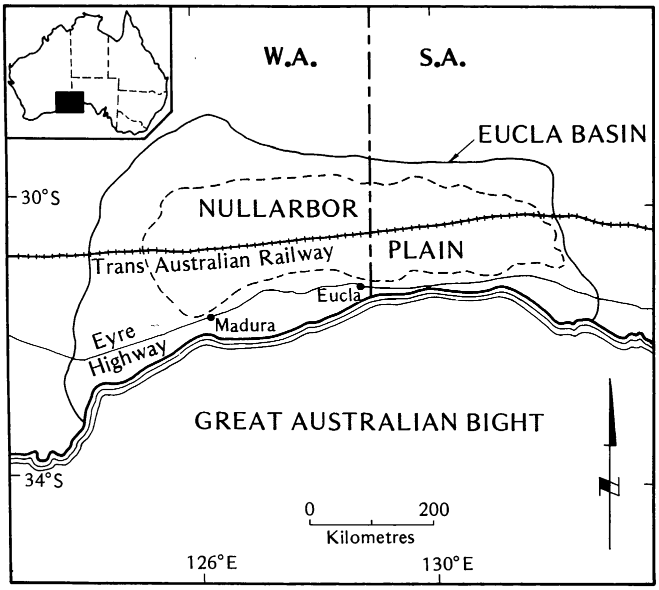

FIG. 1. Location and boundaries of the Nullarbor Plain and Eucla Basin, Australia (after Cleverly, 1976).

of the Great Australian Bight, there are two low-level coastal plains known as the Israelite Plain and Roe Plains.

Although it refers strictly to that physiographic unit of the Nullarbor Region which is devoid of trees (Lat., *nulla arbor* = no trees), the term *Nullarbor Plain* has been used loosely by some authors to include the whole Eucla Basin (*e.g.,* Jennings, 1963). This has led to some confusion in both the geographical and meteoritical literature. Henceforth, for the purposes of describing Western Australian meteorites recovered from the region, the term *Nullarbor Plain* will be used only for that treeless area of the Bunda Plateau as defined by Lowry (1970) and Beard (1975) (Fig. 2).

METEORITE NOMENCLATURE

The problem of naming meteorites from the Nullarbor Region has been overcome by adopting a system of naming and numbering similar to those systems currently employed to deal with the large number of meteorites from Antarctica (Cassidy, 1980) and Roosevelt County, New Mexico, USA (Scott *et al.,* 1986).

Essentially, the main source of geographical names in the Nullarbor Region are the sidings situated at regular intervals along the Trans Australian Railway line (TAR, Fig. 3) bisecting the region from west to east. Additionally, there are a number of officially named pastoral stations and homesteads, caves, rock-holes, dry lakes and boreholes, though these tend to be concentrated along the Eyre Highway (Fig. 1) and do not help meteorite nomenclature for the whole region. To maximize the use of the available geographical names, named *areas* have been delineated in the Nullarbor Region (Fig. 3). Henceforth, new meteorite recoveries from the region will take the name of the *area* in which they are found (*e.g., Forrest*) and a number (*e.g.,* 001) in order of discovery. Initially, only that portion of the Nullarbor Region north of the Eyre Highway has been divided into named areas. This is the region in which the localities of nearly all the recorded meteorite finds from the Nullarbor occur. Out of the past recoveries from the region only three meteorites were found south of the Eyre Highway (Burnabbie, Pannikin and Yayjinna), and there has been only one new recovery. In future, the network of named areas could be extended as required. The names and borders of 47 areas are listed in Table 2. The borders of named areas are delineated on the basis of some natural, and man-made (*e.g.,* railway, fence-lines etc.) boundaries, but also take some cognizance of previous meteorite names and discoveries.

Because the numbers of distinct meteorites collected in any one year from the region are not great, the system of numbering adopted for Nullarbor meteorites is not required to be as elaborate as that currently used for Antarctic meteorites. More importantly, in contrast to the Antarctic situation, many of the meteorites from the Nullarbor Region have probably been recovered from, or near, the sites where they fell and it is possible to map the distribution of finds. Unlike the system of naming and numbering used for Antarctic meteorites, individual numbers will not be allocated automatically to every single meteorite, or fragment of meteorite, recovered from the Nullarbor Region. In accordance with item 4.1 of the *Guidelines for Meteorite Nomenclature* (1980), every effort will be made to ensure that a new recovery does not belong to a previously named meteorite from the same vicinity. Wherever possible, numbers will be allocated only after new recoveries have been recognized as distinct. In this way, it is hoped to minimize the number of any later pairings or generation of synonyms. However, this will not be possible in every case and, in order to expedite their description, two or more meteorites which are only suspected to be from the same fall may be allocated different numbers pending further studies.

Nomenclature and Documentation of Meteorites Discovered Prior to 1970

Documented meteorites from the Nullarbor Region (including those reported in Graham *et al.,* 1985) are listed in Table 1. In general, it is not proposed to rename previously documented meteorites. However, the newly adopted system of nomenclature requires minor amendments to the names of a few past discoveries. For example, where the name of an *area* under the new system of nomenclature has been used previously to name a number of meteorites [*e.g.,* Forrest (a), Forrest (b)], then the meteorites concerned will be allocated numbers (*e.g.,* Forrest 001, Forrest 002). In many cases, only a single find carrying an area name has been reported previously (*e.g.,* Camel Donga, Forrest Lakes, Gunnadorah, Haig, Mundrabilla, Naretha and Reid). On the recommendation of the Nomenclature Committee of the Meteoritical Society, the names of these meteorites shall not be modified. One exception is Carlisle Lakes (a) (Graham *et al.,* 1985), which shall be known henceforth as Carlisle Lakes. Subsequent discoveries from areas carrying the names of previously documented meteorites will be numbered starting from 002.

Fortunately, in only a few cases do the localities of previously documented meteorites carrying area names [*e.g.,* Haig and Rawlinna (stone)] lie outside the newly designated areas with the same name. These meteorites are indicated by asterisks in Table 1. This situation has arisen because the localities of some discoveries were originally uncertain and have since been revised, or that the names allocated to some meteorites were too general for the locality. In addition, a re-examination of past

TABLE 1. Checklist of currently documented meteorite finds from the Nullarbor Region.

Name	Recommended new name	Class/type	Lat. S.	Long. E.	*Area*	Physiographic region	References
1 Billygoat Donga	n.c.	L6	30°08′	126°22′	*Sleeper Camp*	Nullarbor Plain	1, 2, 4, 6, 12
2 Burnabbie	n.c.	H5	32°03′	126°10′	—	Hampton Tableland	2, 4, 6
3 Burrika	n.c.	L6	31°58′	125°50′	*Arubiddy*	Hampton Tableland	2, 4, 6
4 Camel Donga	n.c.	eucrite	30°19′	126°37′	*Camel Donga*	Nullarbor Plain	11
5 Cardanumbi	n.c.	L5	32°06′	125°41′	*Arubiddy*	Hampton Tableland	2, 4, 6, 13
6 Carlisle Lakes (a)	Carlisle Lakes	chanom	29°10′	127°05′	*Carlisle Lakes*	Carlisle Plain	9, 10
7 Cocklebiddy	n.c.	H5	31°56′	126°13′	*Moonera*	Hampton Tableland	1, 2, 6
8 Coorara	n.c.	L6	30°27′	126°06′	*Sleeper Camp*	Nullarbor Plain	6
9 Crab Hole	n.c.	L	30°24′	127°26′	*Mundrabilla*	Nullarbor Plain	10
10 Dingo Pup Donga	n.c.	ureilite	30°26′	126°06′	*Sleeper Camp*	Nyanga Plain	2, 4, 6
11 Forrest (a)	Forrest 001	H5	30°49′	128°13′	*Forrest*	Nullarbor Plain	6, 8, 10
12 Forrest (b)	Forrest 002	L6	30°59′	127°53′	*Forrest*	Nullarbor Plain	10
13 Forrest Lakes*	n.c.	LL5	29°25′	129°30′	—	South Australia	8, 10
14 Gunnadorah	n.c.	H5	31°00′	125°56′	*Gunnadorah*	Nullarbor Plain	6, 10
15 Haig*	n.c.	Iron Om IIIA	31°23′	125°38′	*Balgair*	Nullarbor Plain	1, 2, 3, 6
16 Johnny's Donga#	n.c.	unclassified	*ca.* 30°20′	126°22′	*Sleeper Camp*	Nyanga Plain	1
17 Laundry East	n.c.	H3	31°32′	127°06′	*Madura*	Nullarbor Plain	6, 8, 13
18 Laundry Rockhole	n.c.	H5	31°32′	127°01′	*Madura*	Nullarbor Plain	6, 8
19 Laundry West	n.c.	L4	31°28′	126°56′	*Lynch*	Nullarbor Plain	6, 8
20 Lookout Hill	n.c.	CM2	30°05′26″	128°48′21″	*Reid*	Nullarbor Plain	10, 13
21 Mulga (north)	n.c.	H6	30°11′	126°22′	*Sleeper Camp*	Nyanga Plain	2, 3a, 4, 6, 8
22 Mulga (south)	n.c.	H4	30°12′	126°22′	*Sleeper Camp*	Nyanga Plain	2, 4, 6, 8
23 Mulga (west)	n.c.	C5	30°11′	126°22′	*Sleeper Camp*	Nyanga Plain	8, 9a
24 Mundrabilla	n.c.	Iron. Anom.	30°47′	127°33′	*Mundrabilla*	Nullarbor Plain	1, 2, 3c
25 Nallah	n.c.	H	31°58′	126°15′	*Moonera*	Hampton Tableland	5, 7
26 Naretha*	n.c.	L4	31°00′	124°50′	*Kanandah*	Nyanga Plain	1, 3b, 8
27 North East Reid*	n.c.	H5	30°02′	129°01′	—	South Australia	13
28 North Forrest	n.c.	H5	30°30′	128°06′	*Forrest*	Nullarbor Plain	6, 8, 13
29 North Haig*	n.c.	ureilite	30°13′	126°13′	*Sleeper Camp*	Nyanga Plain	1, 2, 4, 6
30 North Reid	n.c.	LL5	30°00′	128°55′	*Reid*	Nullarbor Plain	6, 13
31 North West Forrest (E6)	n.c.	E6	30°36′	127°49′	*Forrest*	Nullarbor Plain	7, 8
32 North West Forrest	n.c.	H4	30°46′	128°01′	*Forrest*	Nullarbor Plain	7
33 Oak	n.c.	L5	31°35′	127°42′	*Thylacine Hole*	Nullarbor Plain	6, 8
34 Pannikin	n.c.	L6	32°02½′	126°11′	—	Hampton Tableland	2, 4, 6, 8
35 Rawlinna (pallasite)	Rawlinna 001	pallasite	31°10′	125°16′	*Rawlinna*	Nullarbor Plain	2
36 Rawlinna (stone)*	Rawlinna 002	H5	30°22′	126°05′	*Sleeper Camp*	Nyanga Plain	1, 2, 4, 6, 8
37 Reid	n.c.	H5	30°04′	128°59′	*Reid*	Nullarbor Plain	6, 8, 13
38 River	n.c.	L5	30°22′	126°01′	*Sleeper Camp*	Nyanga Plain	2, 4, 6, 8
39 Sleeper Camp	n.c.	L6	30°15′	126°20′	*Sleeper Camp*	Nyanga Plain	1, 2, 4, 6, 8
40 Un-named	Sleeper Camp 002	Iron	30°29′	126°15′	*Sleeper Camp*	Nyanga Plain	6
41 Webb	n.c.	L6	31°41′30″	127°47′	*Thylacine Hole*	Nullarbor Plain	6, 13
42 West Forrest	n.c.	H5	30°45′	127°59′	*Forrest*	Nullarbor Plain	7, 8, 13
43 West Reid	n.c.	H6	30°03′	128°56′	*Reid*	Nullarbor Plain	6, 13
44 Yayjinna	n.c.	L6	32°02′	126°10½′	—	Hampton Tableland	2, 4, 6, 8, 13

* Meteorites which were found outside the newly designated *areas* with same name.
\# Specimen lost.
n.c. = no change.
Amended data (*i.e.*, different from that reported in Graham *et al.*, 1985) underlined, and *area* names in italics.
References: 1. McCall and de Laeter, 1965; 2. McCall, 1968; 3. Cleverly, 1968; 3a. Cleverly, 1972; 3b. Cleverly, 1976; 3c. de Laeter, 1972; 4. McCall and Cleverly, 1968; 5. McCall and Cleverly, 1969; 6. McCall and Cleverly, 1970; 7. McCall, 1972; 8. Mason, 1974; 9. Binns and Pooley, 1979; 9a. Binns *et al.*, 1977; 10. Graham *et al.*, 1985; 11 Cleverly *et al.*, 1986; 12. Cleverly, 1986; 13. This work.

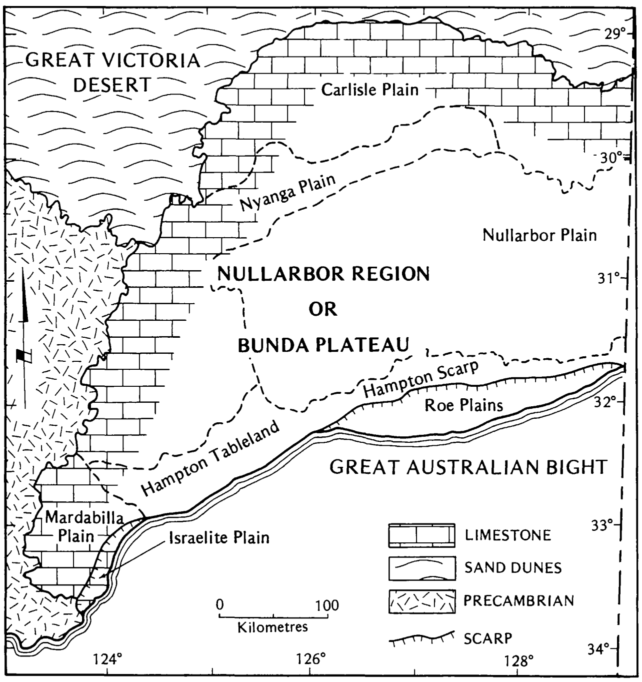

FIG. 2. Physiographic sub-division of the Eucla Basin in Western Australia (after Lowry, 1970; Beard, 1975).

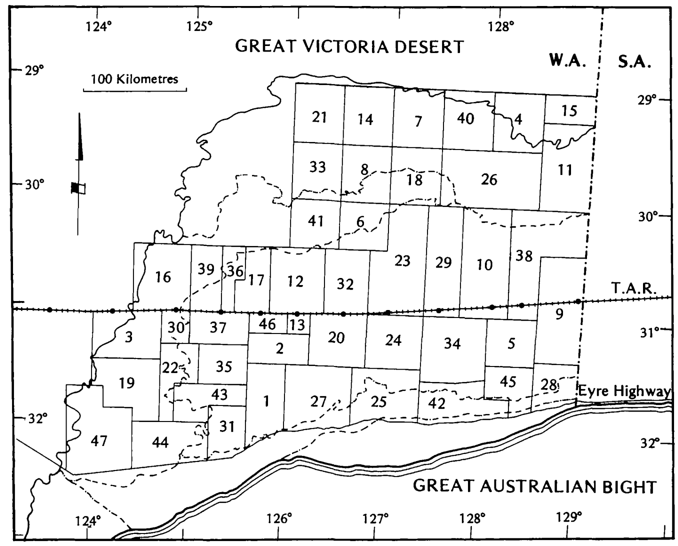

FIG. 3. Division of the Nullarbor Region, Western Australia into geographically named areas for the purposes of meteorite nomenclature. Dot-dash lines show the physiographic sub-divisions named in Fig. 2. Numbers correspond to area names in Table 2.

recoveries from the Nullarbor Region, particularly the ordinary chondrites, has revealed a number of inaccuracies in their documentation. These are discussed below and detailed in Table 1.

The 'Reid' Group of Meteorites

None of the past recoveries of meteorites from the Nullarbor Region that take the name Reid, or have *Reid* as part of their name (West Reid, North East Reid, North Reid—Table 1) were found close to Reid siding on the Trans Australian Railway (Fig. 3). Furthermore, the sites of discovery of the *Reid* group of meteorites (including the CM2 chondrite, Lookout Hill) recorded in Graham *et al.* (1985) are incorrect. The localities of North Reid, North East Reid and West Reid were determined relative to the site of discovery of the Reid meteorite. New information (W. H. Cleverly, pers. comm.) has established that the site of discovery of Reid, originally reported by McCall and Cleverly (1970) as "48 miles (77 km) NNE of Reid" (ca. 30° 11′S, 128° 56′E), is actually 100 km NNE of Reid (*ca.* 30° 04′S, 128° 59′E). The amended co-ordinates for this group of meteorites are given in Table 1. As a consequence of this revision, the find-site of the H5 chondrite North East Reid, recorded as approximately 5 km NE of the Reid meteorite, is now in South Australia not Western Australia. In determining the names of areas for the new system of Nullarbor nomenclature, the anomaly of the *Reid* group of meteorites was taken into account (Fig. 3).

North West Forrest (H) and North Forrest

The discovery before 1969 of two interlocking fragments of stony meteorite weighing 238.4 grams about 14 km NW of Forrest siding on the Trans Australian Railway was reported by McCall (1972). This meteorite, originally named *North West Forrest (1969)* to distinguish it from an enstatite chondrite [now named North West Forrest (E6)] carrying the same name, is currently named North West Forrest (H) and classified by Mason (1974) as H4.

Included under the name North West Forrest (H) in Graham *et al.* (1985) is an additional stone weighing 608.9 grams which has been similarly classified H4 by McCall and Cleverly (1970) and Mason (1974). This stone was found in 1969 approximately 40 km NW of Forrest siding and was originally named *North Forrest* (McCall and Cleverly, 1970). The reason why North Forrest is now listed as a synonym for North West Forrest (H) in Graham *et al.* (1985) is unclear. However, a re-examination shows that these two H-group chondrites differ markedly in degree of crystallinity and state of weathering.

North West Forrest (H) (WAM 13206) consists of numerous well defined chondrules averaging 0.4 mm in diameter set in an opaque iron stained matrix. Most of the detail of the matrix is obscured by terrestrial oxidation and no particles of metal remain unoxidized. Relative to the matrix, the chondrules remain unweathered and, in addition to olivine, contain polysynthetically twinned clinopyroxene and turbid glass consistent with the classification of the meteorite as petrologic type 4.

By comparison with North West Forrest (H), chondrules in North Forrest (WAM 13107) are less distinct and are set in a granular matrix that is not extensively weathered. Particles of metal in North Forrest are extensively oxidized, however some particles of metal have survived. Mineralogically, grains of polysynthetically twinned clinopyroxene are rare, and microcrystallites (10–20 μm) of turbid to clear plagioclase feldspar occur throughout the matrix and in the mesostases of chondrules in North Forrest. These features are consistent with petrologic type 5 rather than type 4 of the Van Schmus and Wood (1967) classification, and distinguish North Forrest from North West Forrest (H).

THE PROBLEM OF 'PAIRING'

Future papers in this series will apply the nomenclature procedure set out above to a large number of meteorite finds from

TABLE 2. Division of the Nullarbor Region, Western Australia into named areas.

Area name	Borders			
	North	South	East	West
1. Arubiddy	31°27′S	EH	126°00′E	125°36′30″E
2. Balgair	31°12′S	31°27′S	126°14′E	125°36′30″E
3. Boonderoo	TAR	31°27′S	124°43′E	124°00′E
4. Boorabie	29°00′S	29°30′S	128°30′E	128°00′E
5. Brambah	30°59′S	31°23′S	128°33′E	128°03′E
6. Camel Donga	30°00′S	30°26′S	127°00′E	126°30′E
7. Carlisle Lakes	29°00′S	29°30′S	127°30′E	127°00′E
8. Colville Lake	29°30′S	30°00′S	127°00′E	126°30′E
9. Deakin	30°24′S	31°19′30″S	129°00′E	128°33′E
10. Forrest	30°00′S	30°59′S	128°15′E	127°45′E
11. Forrest Lakes	29°15′S	30°00′S	129°00′E	128°30′E
12. Gunnadorah	30°26′S	TAR	126°22′E	125°48′E
13. Haig	TAR	31°12′S	126°14′E	126°00′E
14. Jubilee Lake	29°00′S	29°30′S	127°00′E	126°30′E
15. Joondulla	29°00′S	29°15′S	129°00′E	128°30′E
16. Kanandah	30°26′S	TAR	125°00′E	124°25′E
17. Kinclaven	30°26′S	TAR	125°48′E	$
18. Koolgahbin Road	29°30′S	30°00′S	127°30′E	127°00′E
19. Koonjarra	31°27′S	$	124°43′E	$
20. Kybo	TAR	31°27′S	126°49′E	126°14′E
21. Lake Gidgi	29°00′S	29°30′S	126°30′E	126°00′E
22. Lochaber	31°18′S	$	$	124°43′E
23. Loongana	30°00′S	30°59′S	127°23′E	126°49′E
24. Lynch	30°59′S	31°27′S	127°23′E	126°49′E
25. Madura	31°27′S	EH	127°23′E	126°41′E
26. Mason	29°30′S	30°00′S	128°30′E	127°30′E
27. Moonera	31°27′S	EH	126°41′E	126°00′E
28. Moopina	31°19′30″S	EH	129°00′E	128°33′E
29. Mundrabilla	30°00′S	30°59′S	127°45′E	127°23′E
30. Naretha	TAR	31°18′S	125°00′E	124°43′E
31. Nightshade	31°50′S	EH	125°36′30″E	125°13′30″E
32. Nurina	30°26′S	TAR	126°49′E	126°22′E
33. Nyanga Lake	29°30′S	30°00′S	126°30′E	126°00′E
34. Old Homestead	30°58′S	$	128°03′E	127°23′E
35. Pondana	31°18′S	31°39′S	125°36′30″E	125°06′E
36. Premier Downs	30°26′S	TAR	$	125°19′30″E
37. Rawlinna	TAR	31°18′S	125°36′30″E	125°00′E
38. Reid	30°00′S	{ 30°59′S 30°24′S	{ 128°30′E 129°00′E	128°15′E
39. Seemore Downs	30°26′S	TAR	125°19′30″E	125°00′E
40. Shell Lakes	29°00′S	29°30′S	128°00′E	127°30′E
41. Sleeper Camp	30°00′S	30°26′S	126°30′E	126°00′E
42. Thylacine Hole	$	EH	128°19′E	127°23′E
43. Vanesk	31°39′S	$	125°36′30″E	124°52′E
44. Virginia	31°59′S	EH	125°13′30″E	124°25′E
45. Wanteen	31°23′S	$	128°33′	$
46. Wilban	TAR	31°12′S	126°00′E	125°36′30″E
47. Woorlba	$	EH	124°25′E	123°50′E

EH = Eyre Highway.
TAR = Trans Australian Railway.
$ = The northern borders of *Thylacine Hole* (on Mundrabilla Station) and *Woorlba*; the southern borders of *Lochaber, Old Homestead, Vanesk and Wanteen*; the eastern borders of Lochaber and *Premier Downs*, and the western borders of *Kinclaven, Koonjarra* and *Wanteen* are determined by the fence lines which separate these pastoral stations (see Fig. 3).
Numbers correspond to those in Figure 3.

the Nullarbor Region. For some of these recoveries there is the strong possibility that individuals belong to the same fall, or previously documented falls, and this will receive due consideration before names are assigned. As with the large numbers of recoveries from Antarctica (Scott, 1984) and Roosevelt County (Scott *et al.*, 1986), 'pairing' of meteorites can be a somewhat subjective issue. Often, total confidence arises only when two fragments fit together along a shared surface. The factors taken into consideration in assessing Nullarbor pairs, and constraints that apply include the following.

Geographical Proximity

With the exception of cyclonic winds that occasionally move small stones over short distances, there are no other natural transportation processes in the Nullarbor Region. Co-ordinates have been carefully recorded for most meteorites recovered from the Nullarbor and it is even possible to map strewn fields (McCall and Cleverly, 1970; Cleverly, 1972). However, the possibility that some meteorite falls deposit individuals in widely separated localities cannot be discounted. For example, fragments of the observed fall of the Bovedy meteorite in 1969 were found 60 km apart (Meighan and Doughty, 1969), In the Nullarbor Region, fragments of the Mundrabilla iron were found 130 km away from the main strewn field (de Laeter and Cleverly, 1983). New Nullarbor recoveries will be compared with similarly classed meteorites from within a radius of at least 100 km of their findsites.

Mineralogy, Petrography and Metallography

Problems of pairing on mineralogical and petrological criteria arise mainly with the most common types of chondrites. Petrologic classification following the Van Schmus and Wood (1967) scheme can be extended by observing more subtle variations within chondrites of the same type such as sizes, shapes and types of chondrules, mineral grain sizes and microstructural characteristics of secondary plagioclase. Features introduced as the result of pre-terrestrial shock-loading can sometimes be distinctive, though Rubin and Read (1984) have shown that heterogeneity of shock effects on both micro- and macroscopic scales can occur within and between individuals of the same meteorite. Pairing of chondrites containing gross petrologic variations, such as polymict breccias, can present special problems. Atmospheric fragmentation of polymict breccias could conceivably give rise to individuals comprising only one of the petrologic types represented in the parent meteorite.

For equilibrated (types 4–6) ordinary chondrites from Antarctica, Scott (1984) suggested that on the basis of petrographic studies alone the level of confidence in pairing specimens rarely exceeds 90% and, in the absence of cosmogenic radionuclide and noble gas data, could be as low as 50%. In the case of Nullarbor meteorites, accurate documentation of the geographical distribution of falls combined with petrography should allow pairing to at least 90% level of confidence. However, for two or more specimens to be allocated the same name, the level of confidence has to exceed 99%.

Weathering Classification

The classification of meteorite material based on degrees of alteration as the result of terrestrial weathering, introduced for the description of meteorite finds from Antarctica (Cassidy, 1980), provides important additional information to potential researchers in their selection of material and also helps to assess possible pairs. The same classification, based on the extent of oxidation of metal particles, is adopted for the description of meteorites recovered from the Nullarbor Region. However, in addition to the three categories of weathering (A = minor; B = moderate; C = severe), another category of alteration is included that is peculiar to meteorite finds from the Nullarbor Region.

Many stony meteorites from the Nullarbor, even those that appear to have suffered only minor weathering (categories A and B), contain veins and pockets of calcite ($CaCO_3$) derived by solution from the limestone country rock. The symbol x appended to the category of weathering indicates the presence of derived calcite. For example, Bx describes a meteorite that is moderately weathered, but which contains derived calcite.

SUMMARY

Since 1970 a large number of meteorites have been collected from the Nullarbor Region in Western Australia and many more recoveries can be expected in future. A general lack of locality names in the region, and numbers of recoveries which could in future exceed the letters in the alphabet create difficulties in applying the normal procedure for naming meteorites.

To fulfill the main criteria for meteorite nomenclature and to provide a lasting framework for the description of recoveries from the Nullarbor Region, a system of naming and numbering has been devised which distinguishes one meteorite from another and also conveys the approximate geographical location of recoveries.

On the basis of the few available official geographical names and some natural and man-made boundaries, named areas have been delineated in the Nullarbor Region. With the approval of the Nomenclature Committee of the Meteoritical Society, the names of new meteorites recovered from the Nullarbor Region, Western Australia will be determined in future as follows. Meteorite names shall consist of

1. The designated name of the *area* in which they are found (*e.g., Lynch*).
2. Following the *area* name a three digit number (*e.g.,* 001) which differs for each meteorite fall recognized as distinct, and applied in chronological order of discovery for each designated area name.
3. Where the precise localities of distinct meteorites from the region are unknown, they shall take the name *Nullarbor* and be allocated numbers as in 2. above. Since a meteorite called Nullarbor from South Australia is already listed by Graham *et al.* (1985), the next specimen should be called (002).

In general,

4. Every effort shall be made to ensure that a new discovery does not belong to a previously named meteorite from the same area or other adjacent areas.
5. Names of previously documented meteorites shall not be modified to conform to the new system of nomenclature. However, where an area name has been used previously to name more than one meteorite then these will be allocated numbers [*e.g.,* Forrest (a) = Forrest 001; Forrest (b) = Forrest 002].
6. Where pairings are established the lowest number shall be used for the collective meteorite name.

In the future, it is proposed to extend this system of nomenclature to cover meteorite recoveries from the Nullarbor Plain and surrounding region in South Australia.

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Meteorites from the Nullarbor Region, Western Australia: II. Recovery and classification of 34 new meteorite finds from the Mundrabilla, Forrest, Reid and Deakin areas

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Abstract—The discovery of 34 new stony meteorites is reported from those areas of the Nullarbor Region, Western Australia named after Mundrabilla, Forrest, Reid and Deakin sidings on the Trans Australian Railway line. The recoveries include 15 H-, and 15 L-group equilibrated (types 4–6) ordinary chondrites, two distinct H3 chondrites (Mundrabilla 003 and Forrest 003), a genomict H-group chondrite breccia (Reid 011) comprising types 3-6, and one structurally anomalous chondrite (Deakin 001). Seventy-eight distinct meteorites are now known from the region.

INTRODUCTION

OVER THE LAST SEVENTEEN years, approximately 500 specimens of meteorites have been recovered from the Nullarbor Region of the Eucla Basin in Western Australia. Most of this new material, which is deposited at the Western Australian Museum (WAM), has not been described and the total number of distinct meteorites represented has yet to be determined. A description of the Nullarbor Region, which is sub-divided into five distinct physiographic terrains (Nullarbor Plain, Carlisle Plain, Nyanga Plain, Hampton Tableland and Mardabilla Plain) has been provided by Bevan and Binns (1989). To deal with the large number of recoveries and the featureless nature of the region, Bevan and Binns (1989) have devised a system of meteorite nomenclature which currently defines a grid of 47 *areas* each named after geographical localities which they bound (Fig. 1). Newly recovered meteorites take the name of the area in which they are found, and distinct meteorites are allocated three digit numbers (*e.g.,* 001) in order of discovery.

The majority of meteorites recovered from the Nullarbor Region were found by Mr. A. J. Carlisle, a professional bushman, while he and members of his family were hunting for rabbits. Many of the localities of meteorite finds are concentrated into groups which reflect the areas searched by the Carlisle family. It has proved convenient to report new meteorites from the Nullarbor Region in terms of these localised groups, and the named areas in which they occur. In this paper, the second in a series describing meteorites from the Nullarbor Region, details are given of the discovery and classification of 34 new finds of stony meteorites from the *Mundrabilla, Forrest, Reid* and *Deakin* areas.

SAMPLING, CURATORIAL AND ANALYTICAL TECHNIQUES

Polished thin sections were prepared from meteorites (individuals and fragments) found in the named areas under survey. Silicates were analysed using a MAC electron microprobe operated at 15kV and 20.00 nA, and using the energy dispersive procedure developed by Ware (1981). A minimum of ten grains each of olivine and pyroxene were analysed in each sample. Data (Table 2) are presented as the mean and percentage mean deviation (PMD) of analyses. For comparative purposes, and to maintain continuity of analyses between runs, data for olivine were normalised to an independently analysed olivine standard. Petrologic types were assigned according to the Van Schmus and Wood (1967) classification. To identify possible pairs, similarly classed meteorites from within a radius of 100 km of each discovery (including those in named areas adjacent to those surveyed here) were compared petrographically and mineralogically. Names were assigned to distinct meteorites according to the system described by Bevan and Binns (1989).

RECOVERIES

To date, the recovery of twelve distinct meteorites is recorded from the areas of the Nullarbor Region named after Mundrabilla, Forrest, and Reid sidings on the Trans Australian Railway Line (TAR) (Fig. 1). These are listed in Table 1, and the sites of their discovery are shown in Fig. 2. The site of discovery of an additional meteorite, North East Reid, previously recorded by Graham *et al.* (1985) as in Western Australia is now relocated in South Australia (Bevan and Binns, 1989).

Listed in Table 2 are recovery and classification data for 34 new and probably distinct stony meteorite finds. In addition, since 1971, a number of meteorites have been recovered which are fragments of previously documented meteorites. Taken area by area, details of the new and additional recoveries are as follows.

Mundrabilla Area

In accordance with a recommendation by the Nomenclature Committee of the Meteoritical Society, a number has not been appended to the previously known and widely distributed Mundrabilla iron meteorite (Bevan and Binns, 1989). New discoveries from the *Mundrabilla* area are numbered starting from 002. Since the first discovery of a fragment from the Mundrabilla shower in 1911 (then named Premier Downs), at least twelve masses (including a new 3.5 tonne mass found in August 1988) and hundreds of small fragments totalling more than 22 tonnes of material have been recovered from a large area between Loongana and Forrest sidings on the Trans Australian Railway (de Laeter, 1972). Additionally, fragments totalling 3.97 kg from the same fall were found approximately 130 km to the southeast of Mundrabilla siding at Tookana Rock Hole (*q.v.*) (de Laeter and Cleverly, 1983). A portion of the main strewnfield and the find-sites of some of the principal masses of the Mundrabilla shower are shown in Fig. 2.

Since 1971, specimens of ten ordinary chondritic meteorites have been recovered from the *Mundrabilla* area, including five (Mundrabilla 002, 003, 004, 008 and 009) within the strewnfield of Mundrabilla. One L-group chondrite, named Crab Hole (Ta-

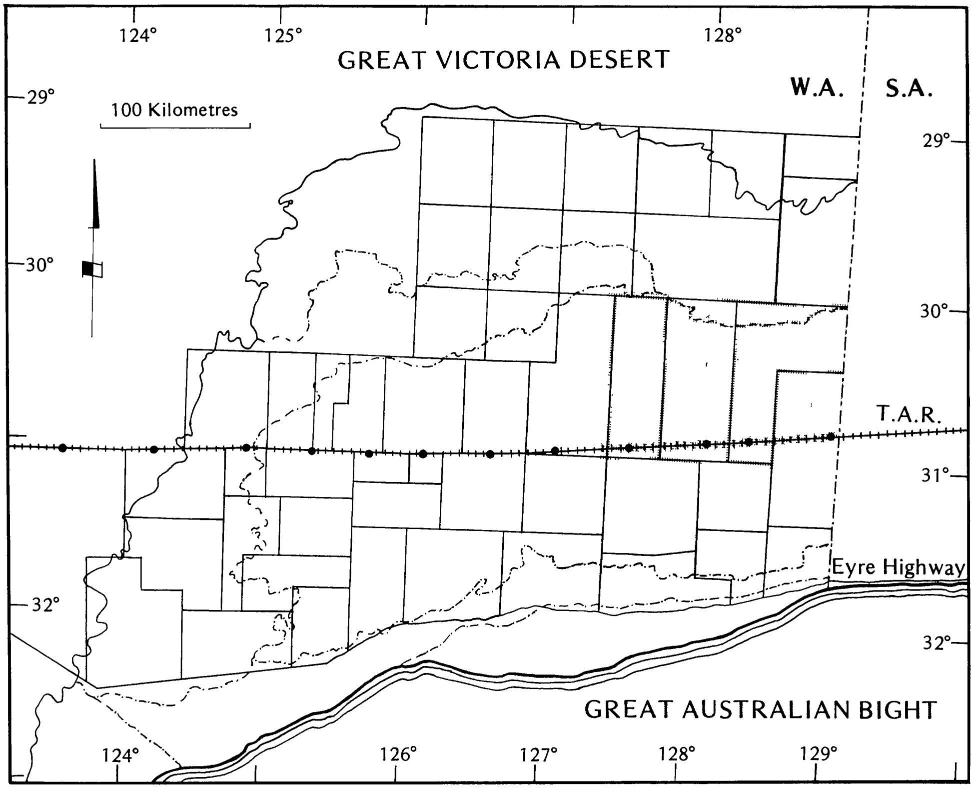

FIG. 1. Nullarbor Region of the Eucla Basin, Western Australia showing 47 *areas* defined by Bevan and Binns (1989). An enlargement of the shaded area is shown in Fig. 2.

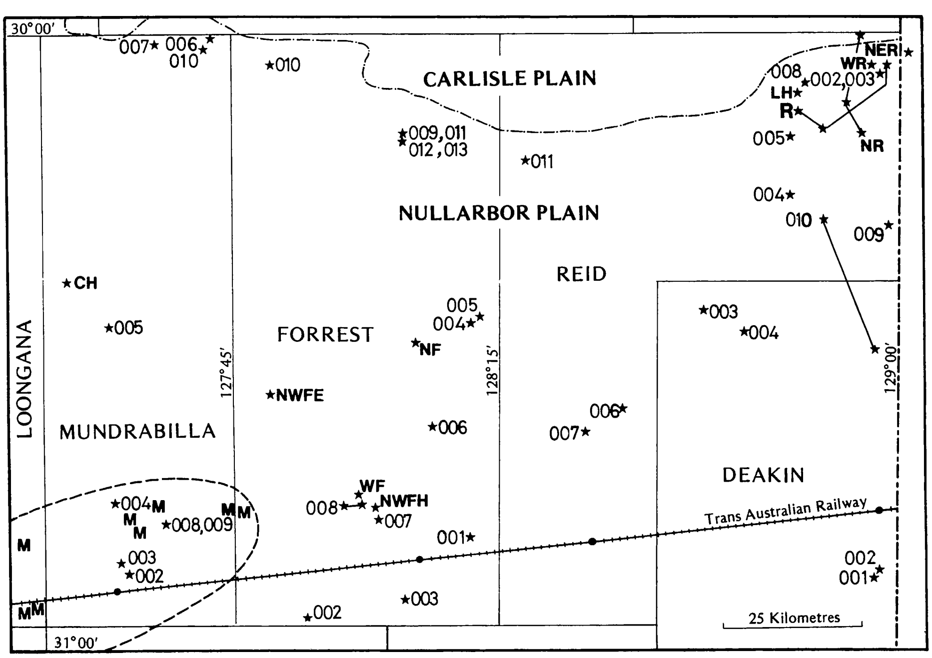

FIG. 2. Sites of discovery of 46 distinct meteorites (includes 34 new recoveries) from the *Mundrabilla, Forrest, Reid* and *Deakin* areas of the Nullarbor Region. Multiple recoveries from the same fall are joined by tie-lines. The strewnfield of the Mundrabilla iron meteorite shower is marked by a dashed line, and the sites of discovery of the principal masses are marked **M. CH** = Crab Hole, **NF** = North Forrest, **NWFE** = North West Forrest (E6), **NWFH** = North West Forrest (H), **WF** = West Forrest, **R** = Reid, **NER** = North East Reid, **WR** = West Reid, **NR** = North Reid, **LH** = Lookout Hill.

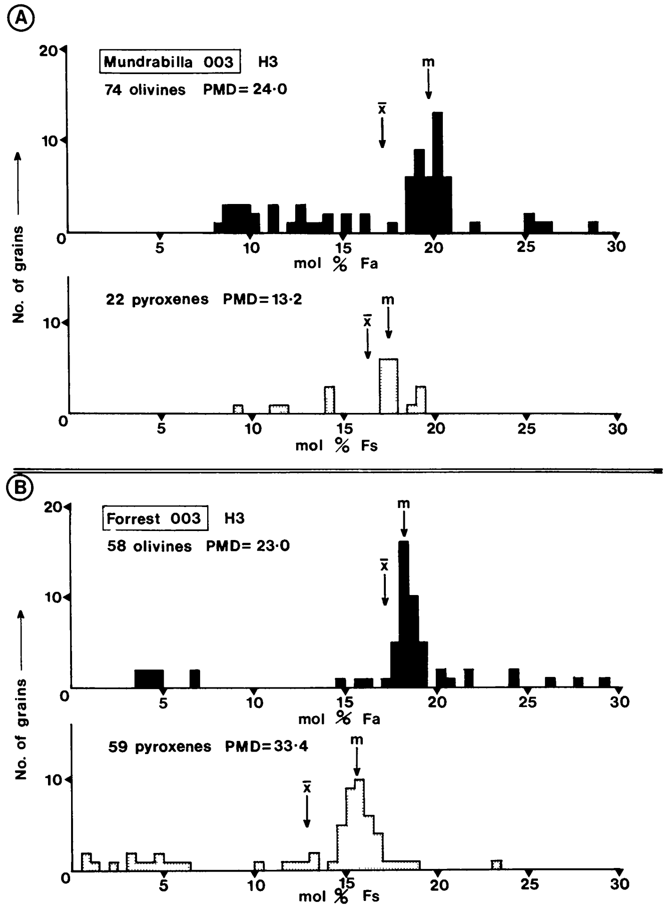

FIG. 3. Histograms of olivine and low-Ca pyroxene compositions in **A**. Mundrabilla 003 and **B**. Forrest 003; x = mean, m = mode, PMD = % mean deviation.

ble 1), was reported to have been found near 'Crab Hole Donga' in 1980, but neither the total weight recovered, nor the locality of this meteorite has been verified (Graham *et al.,* 1985). The majority of the new recoveries are moderately to severely weathered (B-C) ordinary chondrites of high petrologic type (Table 2). Five weathered, irregular fragments of the same H3 chondrite, Mundrabilla 003, were found at one locality 4 km north of Mundrabilla siding. Mundrabilla 003 is highly disequilibrated (Fig. 3) with mean olivine and pyroxene compositions of $Fa_{17.2}$ (PMD 24) and $Fs_{16.4}$ (PMD 13.2), respectively.

Forrest Area

In addition to the six distinct meteorites previously recorded from the Forrest area (Table 1), fragments of eleven new meteorites have been discovered since 1970. All except one are types 4–6 H- and L-group chondrites. A single H3 chondrite, Forrest 003, contains olivine and pyroxene with compositions $Fa_{17.2}$ (PMD 23) and $Fs_{15.6}$ (PMD 33.4), respectively. Despite similarities in mineralogy (Fig. 3) and state of weathering between Forrest 003 and Mundrabilla 003 found 50 km to the west (Fig. 2), the two meteorites are texturally distinct (Figs. 4a,b) and represent separate falls.

Reid Area

To date, four meteorites are recorded from the area named after Reid siding on the Trans Australian Railway (Table 1).

Reid: In addition to the four fragments of this meteorite totalling 144.1 grams recovered from two separate sites (McCall and Cleverly, 1970; McCall, 1972) shown in Fig. 2, another deeply weathered stone weighing 628 grams (WAM 13374) found in 1974 is undoubtedly from the same fall. The new stone, which is the main mass of the fall, was found at a locality approximately 18 km WSW of the original find reported by McCall and Cleverly (1970) and suggests a strewnfield for the fall with a direction from ENE-WSW (Fig. 2).

Reid has been classified as L3 (McCall and Cleverly, 1970), L4 (McCall, 1972) and H4 (Graham *et al.,* 1985). A re-examination (this work) shows that although the meteorite is composed of clearly recognizable chondrules, olivine and pyroxene have uniform compositions of $Fa_{18.9}$ and $Fs_{16.1}$ (PMD 1.8), respectively. Polysynthetically twinned clinopyroxene is generally absent. The composition of the olivine is consistent with that ($Fa_{18.4}$) reported for Reid by Mason (1974) and, together with the microstructural features, indicates that the meteorite belongs to H5 of the Van Schmus and Wood (1967) classification. The

TABLE 1. Nomenclature, classification and geographical co-ordinates of documented meteorites from the *Mundrabilla, Forrest* and *Reid* areas of the Nullarbor Region, Western Australia.

Area	No. of specimens	Total wt.	Class	Weathering	Co-ordinates		
Mundrabilla area							
Mundrabilla	>500	>22 tonnes	IRANOM	A/B	approx.	30°47′S,	127°33′E
Crab Hole	unknown	unknown	L	C		30°24′S,	127°26′E
Forrest area							
Forrest 001	1	97.7 g	H5	Cx		30°49′S,	128°13′E
Forrest 002	unknown	ca. 26 kg	L6	B		30°59′S,	127°53′E
North Forrest	1	608.9 g	H5	Cx		30°30′S,	128°06′E
North West Forrest (H)	1	238.4	H4	Cx		30°46′S,	128°01′E
North West Forrest (E6)	300–400 frags	4.4 kg	E6	Cx		30°36′S,	127°49′E
West Forrest	1	170 g	H5	Cx		30°45′S,	127°59′E
Reid area							
Reid	5	772.1 g	H5	C	first find	30°04′S,	128°59′E
North Reid	3	308.7 g	LL5	B		30°00′S,	128°55′E
West Reid	1	627.7 g	H6	B		30°03′S,	128°56′E
Lookout Hill	1	16.55 g	CM2	A		30°05′26″S,	128°48′21″E

Weathering classification A = minor, B = moderate, C = severe, x = contains derived calcite.

Table 2. Nomenclature, classification and geographical co-ordinates of newly recovered meteorites from the *Mundrabilla, Forrest, Reid,* and *Deakin* areas of the Nullarbor Region, Western Australia.

Name	WAM no.	Date of find	Finder	No. of specimens	Total weight (grams)	Class/type	Weathering	Olivine Fa (PMD)	Pyroxene Fs (PMD)	Location Lat., S	Location Long., E	Structural, mineralogical and petrological remarks
Mundrabilla												
002	13370	1971	A. J. Carlisle	4	251	H5	C	18.9 (2.2)	16.1 (1.8)	30°53′	127°33′	
003	13371	1972	A. J. Carlisle	5	235	H3	Cx	17.2 (24)	16.4 (13.2)	30°51′	127°32′	breccia
004	13377	1975	A. J. Carlisle	3 (frags)	9.2	H5	B/C	19.2 (1.6)	17.4 (1.3)	30°45.5′	127°31.5′	
005	13444	1977	A. J. Carlisle	1	171	H5	B/C	18.3 (0.9)	15.9 (1.7)	30°28.5′	127°31′	
006	13584	1982	A. J. Carlisle	1	24.6	H6	A	19.5 (1.6)	17.6 (−)	30°00.5′	127°42.5′	
007	13588	1982	A. J. Carlisle	1	30.6	L6	Cx	25.2 (0.7)	22.1 (−)	30°01′	127°36.5′	maskelynite
008	13590.1	1982	A. J. Carlisle	1	57.1	L6	B/C	25.5 (1.3)	22.8 (0.4)	30°48′	127°37′	
009	13590.2	1982	A. J. Carlisle	1	25.2	L5	B/Cx	25.6 (0.7)	21.6 (−)	30°48′	127°37′	
010	13587	1982	A. J. Carlisle	3	26.6	L6	B	24.4 (2.0)	20.9 (0.9)	30°01′	127°42′	
Forrest												
003	13366	1970	A. J. Carlisle	1	74	H3	B/Cx	17.2 (23)	12.9 (33.4)	30°54′	128°05′	
004	13367	1970	A. J. Carlisle	1	64	L6	B	24.7 (0.9)	20.5 (0.9)	30°28′	128°12′	flight orientated individual
005	13368	1970	A. J. Carlisle	2	36	H4	Cx	17.9 (0.9)	15.5 (2.7)	30°27.5′	128°13′	
006	13429	1977	A. J. Carlisle	1	47.3	L6	Bx	24.8 (1.7)	20.9 (3.0)	30°38′	128°07.5′	shocked/veined
007	13545	1979	A. J. Carlisle	fragments	910	H4	Cx	18.0 (1.8)	16.3 (1.0)	30°47.1′	128°01′	
008	13546/13547	1979	A. J. Carlisle	2	122.6	L6	B	24.3 (0.8)	20.5 (−)	30°45′	127°59.5′	
										30°45′	127°57′	maskelynite
009	13566-70	1979	Carlisle family	5	1000	L6	Bx	25.4 (1.8)	20.9 (1.3)	30°09′	128°05′	maskelynite
010	13591	1982	A. J. Carlisle	2 (interlock)	359	L4	Bx	25.1 (0.7)	21.4 (−)	30°07′	127°52′	
011	13594.2/.3/.5/.7	1982	A. J. Carlisle	7 (frags)	34.6	H5	C	19.9 (0.8)	17.9 (−)	30°09′	128°05′	
012	13586	1982	A. J. Carlisle	1	28.6	H5	B	19.0 (1.2)	17.6 (−)	30°09′	128°05′	
013	13594.1/.4	1982	A. J. Carlisle	2 (frags)	26.9	L6	C	24.6 (1.1)	21.9 (1.0)	30°09′	128°05′	maskelynite
Reid												
002	13373.1/.5	1974	A. J. Carlisle	2 (frags)	66.5	L6	Cx	24.9 (0.7)	20.9 (1.9)	30°04′	128°58′	
003	13373.2/.3/.4	1974	A. J. Carlisle	6 (frags)	128.7	L5	Bx	24.9 (1.1)	21.6 (1.9)	30°04′	128°58′	
004	13427	1977	A. J. Carlisle	14	295	H5	Cx	18.4 (0.8)	15.9 (1.9)	30°15′	128°48′	
005	13430	1977	J. M. Carlisle	1	42.8	L5-6	Bx	25.6 (1.4)	21.0 (1.1)	30°09′	128°48′	shocked/veined breccia
006	13458	1978	T. Carlisle	80 (frags)	920	H5	Cx	18.0 (0.9)	16.3 (−)	30°36′	128°29′	
007	13595	1982	M. O'Donnell	1	2050	L6	B	25.8 (1.6)	21.6 (−)	30°39′	128°24.5′	
008	13585	1982	A. J. Carlisle	1	221.2	L6	B	25.5 (0.8)	21.8 (−)	30°05′	128°49′	
009	13856	1986	A. J. Carlisle	1	47.8	H4	C	17.9 (2.2)	15.6 (13.2)	30°19′	128°59.1′	
010	13851/52/53/57	1986	A. J. Carlisle	4	8220.3	H6	A	18.9 (1.2)	17.1 (1.0)	30°19.3′	128°51′	main mass 8.1 kg (WAM 13857)
011	13861	1986	C. Bradley	1	4760	H3-6	B	18.1 (2.0)	14.6 (19.0)	30°13′	128°18′	breccia, shocked/veined
Deakin												
001	13460	1978	A. J. Carlisle	1	109.5	CHANOM	C	28.1 (17.8)	21.8 (44.7)	30°53′	128°58′	
002	13462	1978	A. J. Carlisle	5	4.5	H4	Cx	19.0 (3.2)	17.6 (−)	30°53′	128°58.5′	
003	13847	1986	A. J. Carlisle	1	82.6	H5	Cx	19.2 (2.3)	16.9 (−)	30°25.9′	128°40′	flight orientated individual
004	13848	1986	A. J. Carlisle	1	127.9	H4	C	19.3 (1.4)	16.8 (3.0)	30°28.2′	128°44.7′	half of a crusted individual

well defined chondritic nature of the material reported by McCall and Cleverly (1970) appears to be an artifact of weathering.

Crossing the strewnfield of Reid from N-S is an additional strewnfield defined by three specimens of the North Reid LL5 chondrite (McCall and Cleverly, 1970; see Fig. 2). Within the vicinity of the sites of discovery of the Reid, North Reid, West Reid, North East Reid and Lookout Hill meteorites, discoveries have been made of nine additional and distinct meteorites (Table 2). The material includes three distinct L6 chondrites (Reid 002, 005, and 008) and one L5 chondrite (Reid 003) found at the same locality as Reid 002.

Since 1978, 81 fragments of stony meteorite have been recovered from an area 20–25 km east of north from Reid siding. Of the material examined so far, only two additional meteorites are represented.

Reid 006: Eighty fragments probably representing a single, severely weathered and disintegrated H5 chondrite were found in 1978 over an area of a few tens of square metres located approximately 24 km east of north from Reid siding. The largest fragment weighed 243 grams. However, the total weight of all fragments, including some small chips found during a later visit to the same locality, is 0.92 kg.

Reid 007: A partly crusted mass weighing 2.05 kg and representing half an individual was found in 1982 approximately 20 km north of Reid. The meteorite is a thoroughly crystalline L6 chondrite and clearly distinct from Reid 006.

More recently, in 1986, a large (4.76 kg), freshly crusted individual, Reid 011, was found about 70 km west of north from Reid. The meteorite is an unusual genomict breccia of H-group chondrite materials.

Reid 011: The meteorite comprises rounded, light coloured clasts of H4 chondrite intermixed with darker H3 chondrite material (Fig. 4c). In addition, in the section examined, a single, large (up to 2 cm) H6 clast was observed. Generally, there are well defined boundaries between components of different petrologic type. However, locally the H3 and H4 components are intimately intermingled and the boundaries between the two petrologic types are indistinct.

Throughout the meteorite there is abundant evidence of shock-loading, although the degree of shock alteration varies between the different petrologic components. Overall, silicates are fractured and display undulose extinction. Shock-veins and zones of shear deformation pervade the fabric of the meteorite, frequently following the boundaries between petrologic types. In the type 6 clast silicates display mosaic extinction and textures of metal and troilite indicate widespread shock-melting. However, other than in shock-veins, metal and troilite in the components of lower petrologic type mainly show evidence of mechanical alteration.

Deakin Area

To date, material from four distinct falls has been recovered from the area surrounding Deakin siding on the Trans Australian Railway. In addition, three fragments have been found which belong to the main mass of another meteorite, Reid 010, from an adjacent named area (Fig. 2). Three meteorites (Deakin 002, 003 and 004) are severely weathered H-group chondrites (Table 2), a single chondritic stone, Deakin 001, is structurally unusual and may be chemically unique.

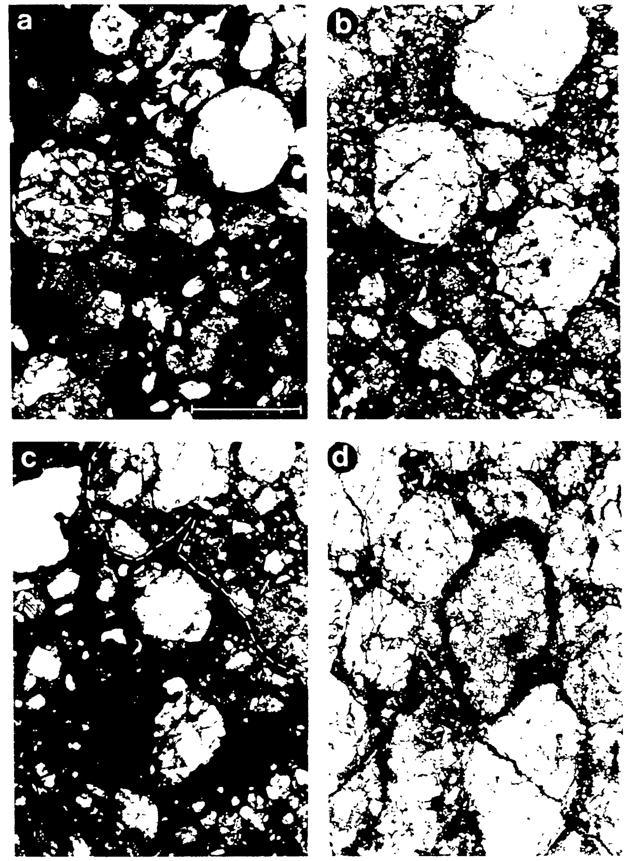

FIG. 4. Transmitted light photomicrographs (PPL) of representative areas of **a.** Mundrabilla 003 **b.** Forrest 003 **c.** Reid 011 (the dashed line marks the boundary between an H4 clast, top right, and H3 matrix, bottom left) and **d.** Deakin 001. Scale bar = 0.5 mm—all photographs same magnification.

Deakin 001: A rounded, and deeply weathered stone weighing 109.5 grams was found south of Deakin in 1978. On cut surfaces, there are no visible particles of metal or sulphide but small patches and veins of limonitic iron oxides testify to the pre-existence of metal/sulphide phases. The stone displays many large (up to 4 mm) tightly packed, ellipsoidal chondrules and chondrule fragments. The outstanding textural feature of Deakin 001 is that the chondrules show a strong preferred orientation with large ellipsoidal chondrules aligned along their major axes. However, overall, the chondrules are so tightly packed that their shapes have been moulded locally by the impingement of other surrounding chondrules (Fig. 4d). Small chondrules trapped between several larger chondrules show highly irregular shapes.

Microscopically, chondrules comprise mainly porphyritic olivine and pyroxene, and radiating pyroxene types, though barred olivine chondrules are also present. The mesostases of chondrules consist of colourless, brown or violet isotropic glass, and large areas display lath-like precipitates of pyroxene. Polysynthetically twinned clinopyroxene is abundant throughout the meteorite. Most grains of clinopyroxene display twin lamellae which are kinked and distorted. Deformation of the twin lamellae is most severe at the points of impingement of pyroxene bearing chondrules. Silicates in Deakin 001 are highly disequilibrated (Fig. 5) with mean olivine and pyroxene compositions of $Fa_{28.1}$ (mode = Fa_{33}) (PMD 17.8) and $Fs_{21.8}$ (PMD 44.7),

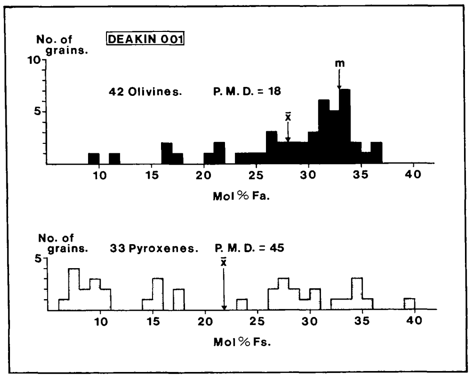

FIG. 5. Histograms of olivine and pyroxene compositions in Deakin 001; x̄ = mean, m = mode, PMD = % mean deviation.

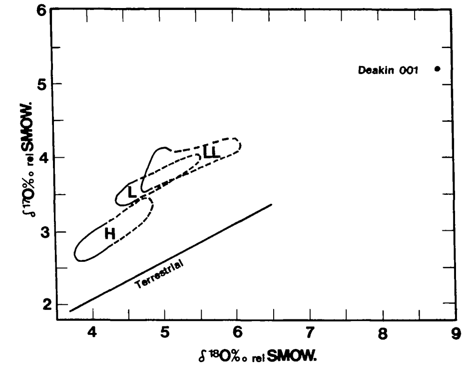

FIG. 6. Bulk oxygen isotopic composition of Deakin 001 (R. N. Clayton, pers. comm.) compared with ordinary chondrites (after Clayton *et al.*, 1976).

respectively. Grains of olivine contain up to 0.3 wt.% CaO, and the wollastonite contents of grains of clinoenstatite vary from 0.0–3.4 mol%.

Texturally, Deakin 001 belongs to petrologic type 3 of the Van Schmus and Wood (1967) classification and the mean compositions of silicates indicate an LL-group chondrite. However, preliminary results for the bulk oxygen isotopic composition of Deakin 001 (R. N. Clayton, pers. comm.) show $\delta^{18}O = +8.8‰$ and $\delta^{17}O = +5.2‰$. The data are consistent with a $\delta^{17}O$ excess of about 0.5–0.7‰ which is similar to that found in H-group chondrites. However, the bulk O-isotopic composition plots in a previously unoccupied region of the three isotope diagram (Fig. 6). Deakin 001 is severely weathered (C*x*) and is partially contaminated by carbonate derived from the limestone country rock of the Nullarbor Region. However, the unusual isotopic composition of Deakin 001 lies a long way up the mass-fractionation line from the ordinary chondrites and is difficult to account for by terrestrial contamination alone.

Deakin 002/003/004: In addition to Deakin 001, fragments of three other meteorites have been discovered in the area. An H4 chondrite, Deakin 002, was found about 800 metres to the east of the site of discovery of Deakin 001. Two severely weathered H-group chondrites, Deakin 003 (H5) and Deakin 004 (H4), were found north of the Trans Australian Railway (Fig. 2). Deakin 004 is petrographically distinct from Deakin 002.

PAIRED SPECIMENS

Generally, in the population of meteorites from the Nullarbor Region, the identification of fragments from the same fall is fraught with the same difficulties as those encountered by Scott (1984) for Antarctic meteorites, and by Scott *et al.* (1986) and Sipiera *et al.* (1987) for recoveries from Roosevelt County. Using the criteria outlined by Bevan and Binns (1989) we have compared the mineralogical and petrographic properties of all the similarly classed ordinary chondrites from the areas studied. Obvious pairings of meteorites, that is those fragments which interlock, are petrographically distinctive, or were found in distinct strewnfields, were made before the allocation of names. However, a number of meteorites which are possibly from the same fall include: Forrest 007 and Forrest 005; Forrest 009, 013 and Mundrabilla 007; Reid 002 and Reid 008. In addition, there are strong similarities between Forrest 008, Forrest 009, 013 and Mundrabilla 007. All of these meteorites are thoroughly crystallized and similarly weathered L6 chondrites containing maskelynite. However, the find site of Forrest 008 lies some 60–90 km south of the find sites of the other meteorites (Fig. 2) and possibly precludes pairing.

SUMMARY AND CONCLUSIONS

Discounting unconfirmed pairings, the 164 specimens representing 34 new meteorites described in this paper bring the total number of distinct recoveries from the Nullarbor Region to 78. The *Mundrabilla, Forrest, Reid,* and *Deakin* areas cover approximately 18×10^3 km², or about one-sixth of the Nullarbor Region in Western Australia. Including previous recoveries (>500 specimens representing 12 distinct meteorites) from the same areas, the density of recovery averages one distinct meteorite fall per 391 km² for the named areas surveyed. Other areas of the Nullarbor which remain to be described show similar, and sometimes greater, densities of meteorite recoveries (Bevan and Binns, *in prep.*). Excluding Antarctica, the density of recovery in the Nullarbor Region is approaching, and may eventually exceed, that (*ca.* one meteorite per 60 km²) in Roosevelt County, New Mexico (calculated from data of Scott *et al.*, 1986; Sipiera *et al.*, 1987) which is currently two orders of magnitude greater than the average (one meteorite per 68×10^3 km²) for the rest of the world's land surface.

No data are available yet on the terrestrial ages of Nullarbor recoveries which would indicate the period over which the observed population of meteorites has accumulated. However, the recent discovery of the Camel Donga eucrite shower (Cleverly *et al.*, 1986) which probably fell within the last five years, shows that the population is constantly being added to.

Some 400 additional specimens of meteorites so far recovered from the Nullarbor Region remain to be described. While the total number of distinct meteorites has yet to be determined, the region has proved to be a prolific area for meteorite finds.

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