THE DEVELOPMENT OF THE STRZELECKI DESERT DUNEFIELDS, CENTRAL AUSTRALIA

With 4 figures and 2 tables

Ernst Löffler and Marjorie E. Sullivan

Zusammenfassung: Zur Entwicklung der Dünenfelder in der Strzelecki-Wüste, Zentralaustralien

In einem früheren Aufsatz postulierten die Autoren, daß große Gebiete der Strzelecki- und Simpson-Wüsten von einem Riesensee – Lake Dieri – bedeckt gewesen waren und daß die regelmäßigen Längsdünen, die heute die Wüsten überziehen, entstanden, als sich Lake Dieri aufgrund fortschreitender Austrocknung langsam zurückzog. Der Sand, der die heutigen Dünen aufbaut, soll größtenteils von ehemaligen Stranddünen stammen, die im Lee des Riesensees entstanden waren und die ihrerseits ihr Material von den von Osten und Nordosten her kommenden Flüssen erhielten.

Zur Verifizierung der Lake Dieri Hypothese wurde eine Reihe von Sandproben entlang zweier Traversen östlich der Salzseen Lake Frome und Lake Callabonna gesammelt und analysiert. Die Analysen zeigen, daß längs des Dünenfelds weder deutliche Unterschiede in der mittleren Korngrößen*sortierung* bestehen, noch daß es deutliche Hinweise in der Korngrößen*verteilung* gibt, die auf unterschiedliche Länge des Sandtransports schließen lassen. Hingegen besteht ein deutlicher Abfall im Feldspatgehalt mit steigender Entfernung von den heutigen Salzseen. Diese Tatsachen zeigen, daß erstens der Sand von einem relativ einheitlichen Liefergebiet stammt, daß zweitens der Sand nicht über das gesamte Dünenfeld äolisch transportiert wurde und daß drittens der Grad der Verwitterung (= Verlust an Feldspat) und damit das relative Alter der Dünen mit größer werdender Entfernung von den heutigen Salzseen zunimmt. Das bedeutet aber, daß sich die Dünen von Osten und Nordosten her entwickelten in Übereinstimmung mit dem Lake Dieri Konzept.

Introduction

In an earlier paper (Löffler a. Sullivan 1978) we suggested from an interpretation of satellite imagery that a former lake occupied much of the area now covered by the dunefields of the Strzelecki and Simpson Deserts, its legacy being series of pans aligned more or less concentrically and following the trend of the present eastern and northern shorelines of the chain of salt lakes between Lake Eyre in the northwest and Lake Frome in the southeast (Fig. 1). Although the inherited pattern recognized suggested a former enlarged lake – Lake Dieri – no supporting field evidence was available.

The existence of a former Lake Dieri has since been accepted by subsequent workers (Wasson 1983 a, b) but there is disagreement as to the development of the longitidinal dunes which we saw as directly linked with the history of Lake Dieri. We argued that the regular longitudinal dunes which extend from the chain of salt lakes in a fan-like pattern developed as Lake Dieri receded, and that the sand originated largely from littoral dunes which formed along the lee side of the lake. With the gradual retraction of the lake shores, new sets of littoral dunes were formed and sand from the older shoreline dunes was blown out and incorporated into the logitudinal dune system.

One of the crucial tests of this interpretation is the relative age of the sand across the dunefield. If it can be established that the dune system developed from outside in, i.e. that sand within the dunes furthest away from the present lake system is oldest and that sand within those nearest to the lake chain is youngest the earlier interpretation would be supported. For this reason a number of sand samples was collected on two traverses across the Strzelecki Desert (Fig. 2) and mechanical and chemical analyses were carried out on the sands to characterize them and to identify any trends which may have bearing on their age or origin. The two traverses followed the only two tracks crossing the desert from west to east and southwest to northeast respectively. Traverse 1 followed the Strzelecki Track from Lake Callabonna to Innamincka and traverse 2 a track from Lake Frome to Hawker Gate (Fig. 2). Because of the proximity of the Strzelecki Creek with its considerable sand load in the first traverse it was difficult to collect sand that was not influenced by recent sand transport from the creek bed and the samples could therefore not be collected in fixed intervals as on the second traverse where two sand samples were taken every ten kilometres. Where possible surface samples were taken from the dune crest where the sand is loose (Samples A) and from the indurated sand at the toe of the dune (Samples B).

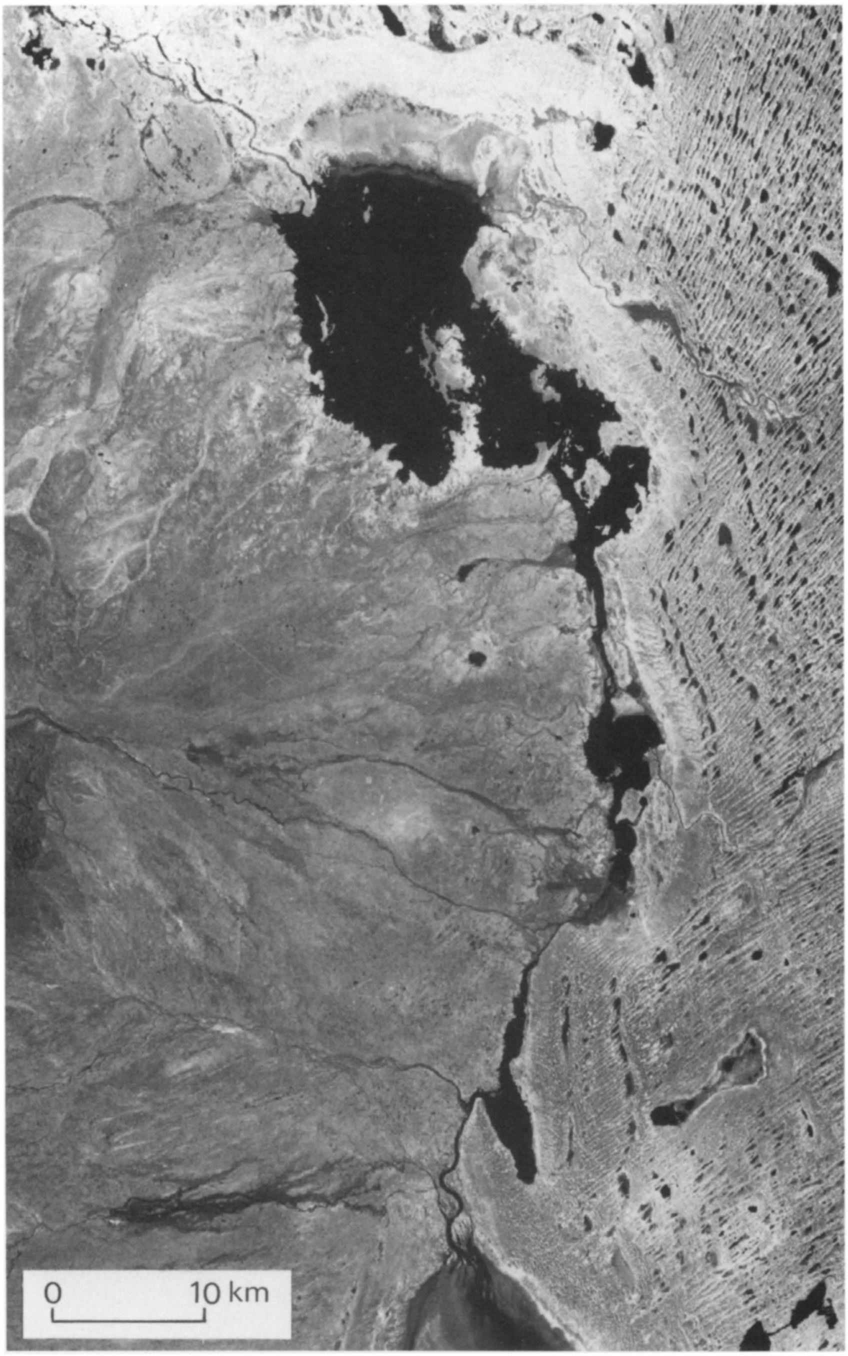

Fig. 1: Landsat image (quarter scene) of northernmost part of Lake Frome and Lake Callabonna (top) and the pattern of aligned pans and northeasterly trending longitudinal dunes east of the lakes. The alignment of the pans transverse to longitudinal dunes is accentuated because the pans are filled with water after heavy rain and show up clearly on the infrared band of the Landsat imagery

Landsatszene (¼ Ausschnitt) mit nördlichem Abschnitt des Lake Frome und Lake Callabonna und dem Muster der nebeneinander gereihten Tonpfannen und Längsdünen östlich der Seen. Das Muster der Tonpfannen wird dadurch hervorgehoben, daß die Tonpfannen zur Zeit der Aufnahme wassergefüllt waren, was sich besonders deutlich auf dem infraroten Kanal (Band 7) zeigt

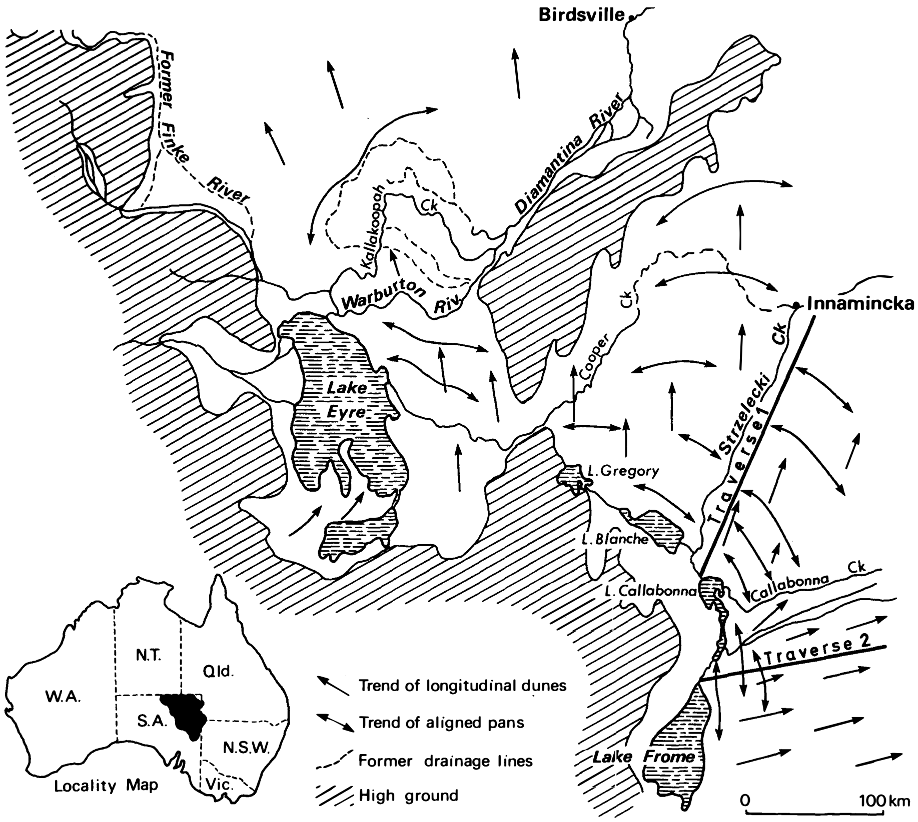

Fig. 2: Locality map with position of traverses
Übersichtskarte mit Angabe der ungefähren Lage der Traversen

Sand analyses

Mechanical analyses of the sand were carried out by dry sieving duplicate 100 g samples through a set of nested Endecott test sieves at 0,5 phi intervals. Cumulative percentage weight values were plotted, sorting and skewness parameters calculated according to the method described by Folk (1974), and descriptions of the sand samples made using Wentworth size classes (Folk 1974). These analyses were carried out to characterize the sands and to detect any major changes which may reflect the origin of the sediment or the method of its deposition.

Optical and chemical analyses were carried out on small subsamples of these sands to determine their contained proportion of feldspar and quartz, and the total amounts of iron (both ferric and ferrous). This was done to detect any chemical changes or variations in the sands that may have some bearing on the relative ages of sands across the dunefield. In particular the increase in reddening across the dunefield has been interpreted as an increase in age (Wopfner a. Twidale 1967). Initially three methods were used on a number of selected samples of traverse 1 to determine the feldspar/quartz ratios in order to establish the most economic working method.

The three methods are:

1. Analyzing the sand for Al, Na and K and calculating the amount of feldspar. A representative sample was agitated in water with sodium hydroxide and calgon to disperse the sediment and remove clay from the sand grains. The clean sand was then submitted for chemical analysis to determine the proportions of the feldspar cations.
2. Making a thin section from a resin-impregnated block of clean sand and counting the proportion of quartz and feldspars in 500 grains on the assumption that there is no systematic difference in grain size between quartz and feldspar sand grains.
3. Preparing a resin impregnated block of clean sand, staining the surface using hydrofluoric acid

and sodium cobaltnitrate, and point counting for quartz, potassium feldspar and plagioclase.

The results of the analyses are shown in Table 1. The results of all three methods were similar in so far as they were internally consistent however the total amount of feldspar varied between methods with the total amount the feldspars being considerably lower in method 2 than in methods 1 and 3.

The very low count of feldspar grains in method 2 is partly due to the difficulties of differentiating microscopically between quartz and feldspar. Grains below 30 to 40 μm in size were not counted because of the increased difficulties of identification, due in particular to the decreased chance of characteristic feldspar twinning being displayed in a small area.

Also feldspar grains may have been mis-identified as quartz in cases where they are untwinned or oriented not to show twinning, or do not show signs of cleavage or alteration. An underestimate of the amount of feldspar is therefore likely.

Methods 1 and 3 however produced similar results even though the exact amount of feldspar may differ. Only these two methods were used for analyzing the samples collected at a later date along traverse 2. We consider method 1 to be the most satisfactory because it produced the most consistent results and is simplest and cheapest.

Results of the mechanical and chemical analyses

Mechanical analyses of the dry sand indicated a relatively uniform body of sand throughout the sampled area. The sand was moderately to moderately well sorted, fine skewed fine to medium sand. Local examples of coarse skewed sand occurred, generally from near pan surfaces where a more gravelly lag was concentrated.

From both transects but particularly from transect 2, it was apparent that the upper loose sand was slightly coarser than the basal sand. The sand of the dunes of traverse 2 is more uniform than those from traverse 1 and the reason for this is probably the proximity of the Strzelecki Creek bed in traverse 1. In all samples of traverse 2 the upper loose sand (a) is moderately well sorted, fine skewed medium sand, while the lower (b) sample is invariably slightly less well sorted fine skewed fine sand (Fig. 3).

In the samples from traverse 1 the same trend is present but less well defined, with the upper loose sand being slightly better sorted and slightly coarser than the lower sand. The upper sand is moderately sorted coarse skewed to symmetrical fine sand.

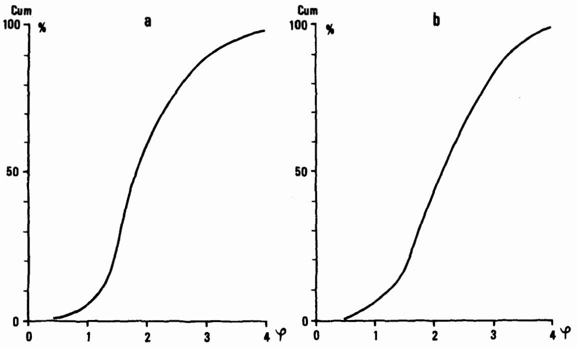

Fig. 3: Typical examples of sorting curve of upper (a) and lower (b) dune sand

Typische Beispiele der Sortierungskurve eines Dünensandes. a: Sand vom Dünenkamm, b: Sand von der Basis der Düne

The chemical analyses show that there is no apparent trend in the iron content (both ferric and ferrous) with increasing distance from the lakes (Tables 1, 2), despite an obvious change in colour from pale yellow to bright red across the dune field. This is in agreement with general observations that the amount of iron is no measure for redness in dune sands (GARDNER a. PYE 1981). WASSON's (1983 b) results show a slight increase in iron content from west to east, but as WASSON points out his sample is too small to draw any conclusions. Only two samples of his traverse show higher iron content. Our results also do not support his conclusion that the red sands have a higher iron content than the pale sands. If anything there is a slightly higher iron content in the pale sands near the salt lakes (Tables 1, 2).

The lack of any systematic differences in modal grain size sorting across the dunefield and the relative consistant Fe content indicate that the dune sands probably derived from a single sand source of mixed sediments. Since there is also no indication from the grain size distribution of great differences in the distance over which sands have been transported, it is unlikely that the dune sands were transported by wind across the whole dunefield, a result that is also supported by the findings of WASSON (1983 a). The difference between upper and lower dune sand probably indicates the effect of prolonged illuviation moving shightly finer sand fractions from the upper sand into the lower horizon (see e.g. CORBETT 1969, TWIDALE 1981). While there is no difference in sorting from one end of the dunefield to the other there is a striking decrease in feldspar content with increasing distance from the present lakes. Again this trend is

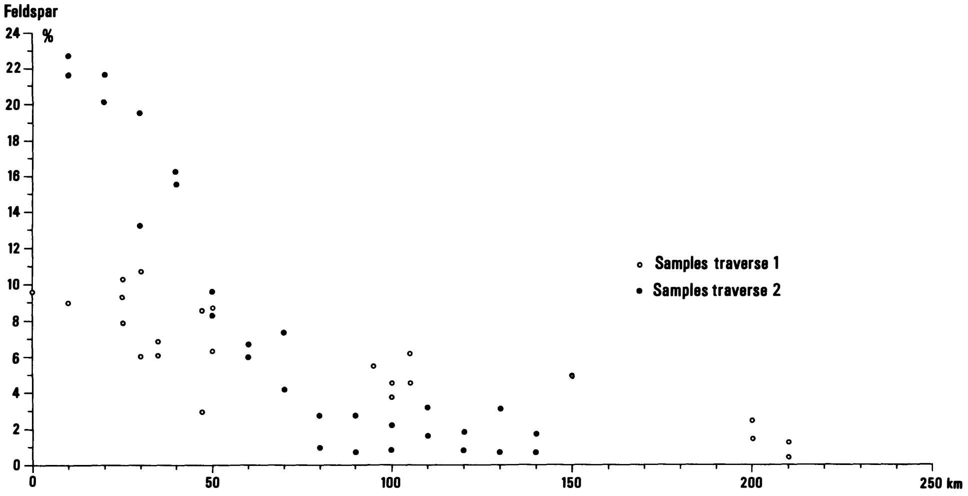

Fig. 4: Feldspar content in dunes across Strzelecki Desert using results from Method 1
Feldspatgehalt (nach Methode 1) der Dünen entlang der Strzelecki-Wüste

Table 1: Feldspar and total iron content of dune sands traverse 1. Note that Method 3 was not carried out on all samples. Dash indicates no analysis

Feldspat- und Gesamteisengehalt der Dünensande von Traverse 1. Beachte: Methode 3 wurde nicht für alle Proben durchgeführt; dies wird durch einen Querstrich (-) vermerkt

Sample	Distance from Lake Callabonna	Method 1 % feldspar	Method 2 feldspar grains in 500	Method 3 % feldspar	Total iron
1 A	210	0.6	6	2	0.35
1 B		1.6	3	2	0.69
2 A	200	1.7	3	3	0.49
2 B		2.45	4	2	0.74
3	150	4.9	17	-	0.83
4 A	105	4.6	4	-	0.40
4 B		6.2	4	-	0.43
5 A	100	3.8	4	9	0.87
5 B		4.5	0	9.7	0.66
6	95	5.5	13	-	0.40
7 A	50	6.2	6	-	0.46
7 B		8.5	15	-	0.83
8 A	47	4.14	14	3.5	0.50
8 B		7.4	18	9	0.71
9 A	35	6.9	4	-	0.44
9 B		6.1	9	-	0.87
10 A	30	6.0	14	-	0.67
10 B		10.8	15	-	2.13
11 A	25	9.3	13	9.8	0.12
11 B		7.9	12	12.8	0.87
12	24	10.3	15	-	0.61
13	10	9.0	14	-	1.07
14	0	9.6	20	-	0.77

Table 2: Feldspar and total iron content of dune sands traverse 2

Feldspat- und Gesamteisengehalt der Dünensande von Traverse 2

Sample	Distance from Lake Frome	Method 1 % feldspar	Method 2 % feldspar	Total iron
1 A	140	0.8	1.6	0.63
1 B		1.9	1.4	0.98
2 A	130	0.9	0.4	0.77
2 B		3.3	1.2	0.97
3 A	120	0.9	1.7	0.70
3 B		2.0	2.9	0.76
4 A	110	1.5	1.5	0.70
4 B		3.2	1.1	0.76
5 A	100	0.9	2.6	0.81
5 B		2.4	3.6	0.97
6 A	90	0.5	4.0	0.73
6 B		2.8	0.8	0.73
7 A	80	1.4	1.5	0.67
7 B		2.8	1.7	0.91
8 A	70	4.3	3.8	0.73
8 B		7.5	2.0	0.80
9 A	60	6.0	7.1	0.76
9 B		6.8	7.2	0.84
10 A	50	9.5	8.3	0.64
10 B		8.4	4.2	0.84
11 A	40	15.5	11.1	0.87
11 B		16.2	10.4	0.85
12 A	30	19.5	11.7	0.76
12 B		13.2	13.2	1.07
13 A	20	21.7	15.5	0.81
13 B		20.3	13.0	1.11
14 A	10	21.7	15.6	1.04
14 B		22.8	16.5	1.20

more pronounced and more consistent in traverse 2 than in 1 (Fig. 4, Tables 1, 2), where the amount of feldspar decreases from 1–2% at the outer margin of the dunefield to 15–20% near the present salt lakes.

Discussion and conclusions

Both the mechanical analyses and the iron analyses indicate the likelihood that there was a relatively homogeneous sand source for the dunefield of the Strzelecki Desert and that the difference between the loose top sand layer and the often indurated "core" of the dune may be due to local reworking and illuviation of clay from top to base. There is no trend in the amount of iron with increasing distance from the present lakes, nor does the sand sorting show any significant trends except that the sand appears slightly finer near the present lakes. The slight increase in Fe downwards in the dune profile indicates eluviation of clay minerals and sand coatings from the upper loose sands and illuviation into the lower parts of the dune. This eluviation/illuviation also causes the differentiation of the "dune profile" into slightly coarser well sorted upper sands and slightly finer less well sorted lower sands.

The most important fact with respect to our Lake Dieri concept, however, is the clear trend towards an increase in the quartz/feldspar ratio with increasing distance from the present lakes and hence an increase in weathering and relative age across the dunefield. while we do not know how the lake receded and how significant fluctuations and occasional regressions may have been there can be no doubt that the outer margins of the lake were exposed first and that the dunes occupying this area and the area downwind of it were formed from the sand which was exposed earlier while the dunes further west and south were formed from sand exposed later.

The littoral dunes of Lake Dieri probably provided a uniform single sand source of mixed sediments derived from drainage into the lake basin from predominantly quartzitic and granitic rocks exposed in the uplands to the N and E. This function as a distributor of sand laterally across the lake and along the lake shore (and hence across the present dunefield at right angle to the predominant wind direction) from the mouths of the main rivers is an important role as the sand of the Strzelecki Desert can not have derived from the small catchments of the rivers draining the Flinders Ranges nor can it have derived from a local source beneath the present dunefield which in the central and southern Strzelecki Desert consists of Tertiary clays. Lateral transport of sand must be considered in any hypothesis that tries to explain the Strzelecki Dunefields. WASSON (1983 a) has argued against this concept of longitudinal dunes developing from lake fringing dunes on the grounds that most of the sediments underlying the northern Strzelecki and Simpson deserts are alluvial in origin. However he does agree that the aligned pans must be remnants of lacustrine strandlines of some kind if only for the reason that "there is no other explanation for it". He also presents evidence from an area east of northern Lake Frome where in fact longitudinal dunes have developed from transverse lake fringing dune ridges.

We do not see any real contradiction between WASSON's explanation that "the longitudinal dunes east of Strzelecki Creek have been formed by aeolian redistribution of lacustrine sediment, lake-shore transverse dunes and beach deposits, and fluviatile deposits" (WASSON 1983 a, p. 112) and our Lake Dieri concept. WASSON's (1983 a) findings that in the area west of Strzelecki Creek the dune material derived from muddy alluvium and in the southern Simpson Desert from deflation of pans are also not contradicting our concept since there is no denying that ultimately all the dune material derived from the uplands to the east, northeast and north and was brought into the basin by major river systems draining the eastern highlands. The question, however, as to how these deposits were distributed across the dunefields transverse to the general wind direction can as far as the Strzelecki Desert is concerned not be answered by alluvial redistribution alone. Lateral transport of the sediments along a former lake shore must be involved.

Our original interpretation represented an attempt to explain a pattern clearly visible on the satellite imagery and the striking pattern of aligned pans is still one of our strongest arguments for the existence of Lake Dieri. From the satellite view coming down to earth has proved more difficult and unequivocal evidence for the existence of the lake has so far not been found. The published stratigraphy of the lake basin is complex (cf. WASSON 1983 a) and there ist still no information on the timing of the lake or the events following its disappearance (CALLEN 1977, KING 1956, WOPFNER a. TWIDALE 1967). However we feel that the data presented here and in particular the clear trend of the quartz/feldspar ratio with increasing distance from the present remnant lakes do support our view of the existence of a former Lake Dieri followed by the establishment of the present dunefields in the Strzelecki Desert.

Acknowledgements

The work on which this paper is based was undertaken while the authors were members of the Division of Land Use Research (now Division of Water and Land Resources), CSIRO, Australia. The laboratory analyses were carried out by the Australian Mineral Development Laboratories and financed by the Division of Land Use Research. This is gratefully acknowledged.

References

CALLEN, R. A.: Late Cainozoik environments of part of northeastern Southaustralia. In: J. Geol. Soc. Aust. 24, 1977, 151-169.

CORBETT, J. R.: The Living Soil. Sydney 1969.

FOLK, R. L.: The petrology of sedimentary rocks. Austin, Texas 1974.

GARDNER, R. a. PYE, K.: Nature, origin and palaeoenvironmental significance of red coastal and desert dune sands. In: Progress in Physical Geography 5, 1981, 514-534.

KING, D.: The Quaternary stratigraphic record at Lake Eyre North and the evolution of existing topographic forms. In: Trans.R.Soc.S.Aust. 79, 1956, 93-103.

LÖFFLER, E. a. SULLIVAN, M. E.: Lake Dieri resurrected: an interpretation using satellite imagery. In: Z. Geomorph. N.F. 23, 1979, 233-242.

TWIDALE, C. R.: Age and origin of longitudinal dunes in the Simpson and other sand rigde deserts. In: Die Erde 112, 1981, 231-247.

WASSON, R. J.: The Cainozoic history of the Strzelecki and Simpson dune fields (Australia), and the origin of the desert dunes. In: Z. Geomorph. N.F., Suppl. Bd. 45, 1983 (a), 85-116.

– : Dune types, sand colour, sediment provenance and hydrology of the Strzelecki-Simpson dunefield, Australia. In: BROOKFIELD, M. E. a. AHLBRANDT, T. S. (Eds.): Eolian Sediments and Process, Amsterdam 1983 (b), 165-195.

WOPFNER, H. a. TWIDALE, C. R.: Geomorphological evolution of the Lake Eyre Basin, central Australia. In: JENNINGS, J. N. a. MABBUTT, J. A. (Eds.): Landform studies from Australia and New Guinea. Canberra 1967, 118-143.

BERICHTE UND MITTEILUNGEN

URBAN HEAT ISLAND DEVELOPMENT IN MEDIUM AND LARGE URBAN AREAS IN MEXICO

With 4 figures and 1 table

ERNESTO JAUREGUI

1. *Introduction*

A typical example of man-made modifications on the city climate due to the urbanization process is the so-called heat island effect. The phenomenon of air temperature often being higher in the city than in its surrounding country side, has long been recognized and documented for mid-latitude cities. Studies on heat island effects are so numerous for the temperate zone that it seems possible now to draw some generalizations regarding its morphology and time variations (see for example OKE 1982).

By contrast, urban climate studies in the tropics are relatively recent and very sparse. The few studies that have been undertaken in tropical cities have been mainly based on urban/rural thermal contrasts established from climatological records. The need for information on tropical urban climates has been