The Thuathe meteorite fall of 21 July 2002

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The Thuathe meteorite fell on 21 July 2002 between 15:45 SAST (first sightings) and 15:49 (local sightings). The meteorite is classified as an H4/5 type ordinary chondrite, confirmed by whole rock and mineralogical analyses. The minerals found in the meteorite were kamacite, troilite, albitic plagioclase, forsteritic olivine, diopside, enstatite, and chromitic spinel. Temperatures were obtained from the orthopyroxene-clinopyroxene, orthopyroxene-olivine and clinopyroxene-olivine systems, that yielded values of 1200–1600°C. With respect to average chondrites, the Thuathe meteorite samples are depleted in Zr, and enriched in Rb, Th, Ta, Ba, La, Sr, Sc, Co and Ni.

Introduction

The Thuathe bolide entered the atmosphere above southern Africa on Sunday, 21 July 2002 at approximately 15:45 SAST. A possible position of impact was determined from reports of fireball sightings, sounds and shock waves. Eyewitness reports were requested from police stations, farmers, tour operators and many others in the southern and eastern Free State, South Africa. Positive responses were mapped in terms of direction of sighting. The locations of observers were determined with a global positioning system and compass bearings were taken of sighting directions. All led to approximately the same area within Lesotho (Fig. 1). The general appearance of a piece of the meteorite is shown in Fig. 2.

Witnesses were asked to complete a 'meteor reporting form' (Table 1), which included date and time of sighting, tremors and sounds. If possible, latitude and longitude were provided, together with direction of sighting. Other information included light intensity and colour of the meteorite trail, velocity, duration of light and sound, and fragmentation. The purpose of this communication is to report the sightings and to provide the first analytical results obtained from specimens.

The Thuathe fall was experienced as a meteorite shower. At least 500 meteorite stones of various sizes have been recovered.[1] The samples collected range in size from a few grams to 2.3 kg, and are irregular in shape. All of them contain chondrules and exhibit dark brown fusion crusts.

Chemical composition. The Thuathe meteorite proved to be an ordinary chondrite, intermediate between enstatite and carbonaceous chondrites. The chemical composition (Tables 2, 3) of chondrites facilitates classification. Major and trace-element analyses of whole rock samples were conducted by means of ICP-MS in the Geology Department on the Durban campus of the University of Natal. Entire samples were dissolved using an Anton Paar multiwave microwave sample preparation system, high temperature and high pressure to solution.

Petrography and mineralogy. Under the microscope, several metal, sulphide, oxide and silicate phases could be distinguished. A Cameca Camebax electron microprobe was used with a 3-micron microbeam (15 kV and 30 nA) to identify the different minerals (PAP corrections and standards were used). The sulphide phase was troilite with subordinate chalcopyrite, and the oxide was chromite. The silicate phases included albitic plagioclase (an ~20%) and forsteritic olivine (fo ~85%). Pyroxene proved to be enstatitic (Fig. 3) and pigeonitic.

Metamorphic temperatures. In the absence of a succession of

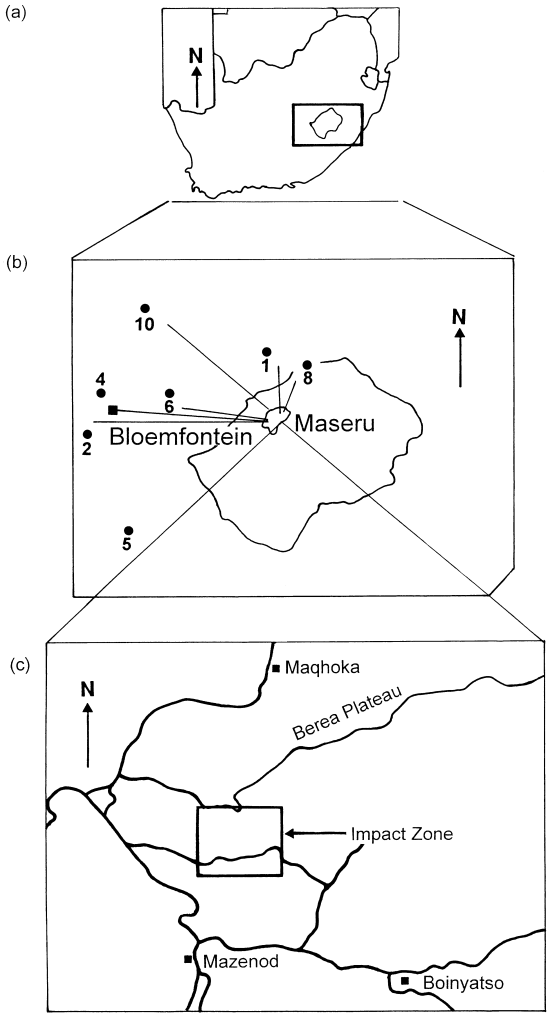

Fig. 1. **a**, Locality map. **b**, Position and direction of observations, numbers refer to Table 1. **c**, The approximate 25-km^2 impact zone. Scale 1:430 000.

Fig. 2. Photograph showing the general appearance of a sample of the Thuathe meteorite.

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Table 1. Summaries of eye witness reports of the Thuathe meteorite observed on 21 July 2002.

No.	Time SAST	Location of observer	Bearing from observer	Fireball duration	Fireball colour	Perceived velocity	Sounds, shock waves or or other general comments
1	15:50	Umpukane Farm on Clocolan/Marquard road 28°50′12″S, 27°30′25″E	175° Moving vertically downwards	4 s	White	Fast	No sounds or shock waves heard or felt.
2	15:48	Bloemfontein/Petrusburg road 29°35′15″S, 26°10′19″E	098° Moving vertically downwards	5s	White	Very fast	No sounds or shock waves heard or felt.
3	15:50	Alpha Estates Farm, Ladybrand district on Lesotho border	n/a	n/a	n/a	n/a	Shock waves felt.
4	15:50	Loch Logan, Bloemfontein 29°06′49″S, 26°12′34″E	100°	2 s	Whitewith orange tail	Fast	No sounds or shock waves heard or felt.
5	Approx. 16:00	Rouxville Smithfield Road 30°15′48″S, 26°40′30″E	022°	n/a	n/a	n/a	n/a
6	Approx. 16:00	Botshabelo Mountain. 29°15′10″S, 26°45′30″E	095°	2 s	White	Fast heard or felt.	No sounds or shock waves
8	15:50	Pilot flying halfway between Ficksburg and Maseru	Moving vertically downwards	n/a	Light orange	Fast	Flew through meteor smoke trail at 40 000 ft at approx. 29°10′00″S, 27°45′00″E
9	Approx. 16:00	Farm Goedehoop, Ladybrand district	n/a	n/a	n/a	n/a	Loud sound heard from Maseru.
10	Approx. 16:00	Farm Leeufontein in Theunissen district	150°	4 s	White	Fast	No sounds or shock waves heard or felt.

Table 2. Major element analysis of two samples of the Thuathe meteorite in mass percentage.

Element	Maseru A	Maseru B
SiO_2	34.29	34.88
Al_2O_3	1.90	1.97
FeO	33.46	32.66
MnO	0.29	0.30
MgO	21.91	22.38
CaO	1.53	1.61
Na_2O	0.82	0.66
K_2O	0.09	0.09
TiO_2	0.09	0.10
P_2O_5	0.24	0.25
Cr_2O_3	0.48	0.49
NiO	1.94	1.77
S	2.80	2.90
	99.84	100.06

well-defined and experimentally calibrated mineral assemblages, mineral compositions are customarily used to infer metamorphic temperatures and pressures experienced by ordinary chondrites.[2] The systems orthopyroxene–clinopyroxene, orthopyroxene–olivine and clinopyroxene–olivine[3] were used for reference, from which temperatures of 1200–1600°C were deduced.

The metamorphic grade of the ordinary chondrite is difficult

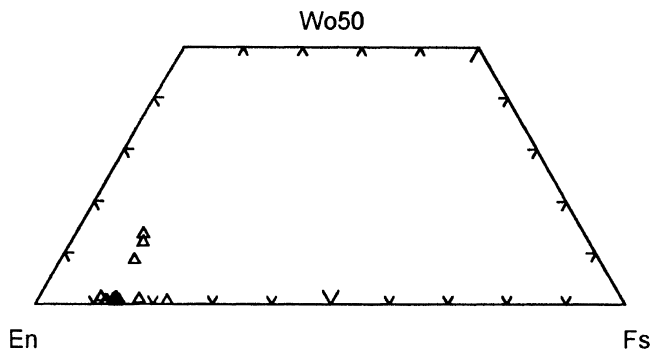

Fig. 3. Compositional distribution of pyroxene from the Thuathe meteorite as depicted on the pyroxene quadrilateral trapezium.

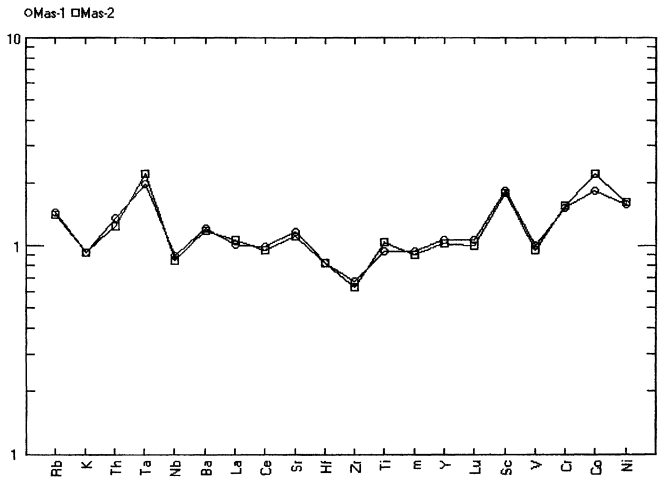

Fig. 4. Chondrite normalized chemical variation of two stones from the Thuathe meteorite plotted on a spidergram to determine its relative enrichment/depletion with respect to chondrite (after Wood[5]).

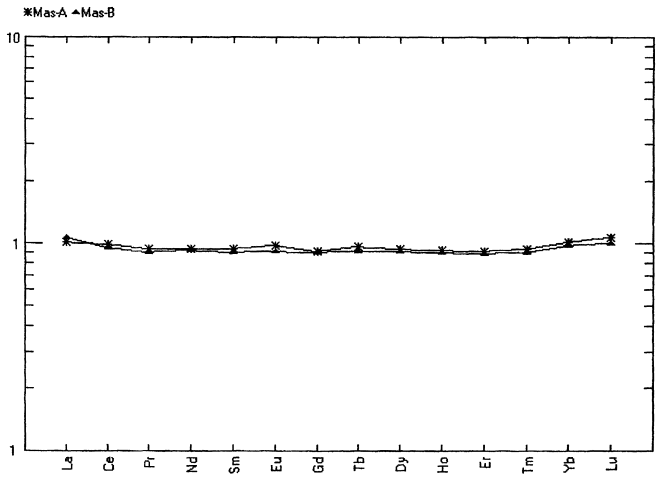

Fig. 5. Chondrite normalized REE (rare-earth element) distribution pattern from the Thuathe meteorite (after Sun[6]).

Table 3. Trace element analysis of two samples of the Thuathe meteorite in mass percentage.

Element	Maseru A	Maseru B
P	1 145.835	1 130.428
Sc	9.215	8.815
V	45.990	44.362
Co	814.078	989.599
Ni	14 055.402	15 459.993
Cu	89.866	83.806
Zn	60.880	59.333
As	1.662	2.624
Rb	2.566	2.486
Sr	11.505	11.033
Y	2.021	1.947
Zr	5.746	5.422
Nb	0.471	0.452
Ba	4.127	3.824
La	0.314	0.330
Ce	0.807	0.777
Pr	0.115	0.111
Nd	0.561	0.551
Sm	0.181	0.73
Eu	0.071	0.067
Gd	0.239	0.236
Tb	0.045	0.043
Dy	0.305	0.296
Ho	0.067	0.066
Er	0.195	0.189
Tm	0.031	0.030
Yb	0.210	0.204
Lu	0.034	0.032
Hf	0.149	0.148
Ta	0.041	0.046
W	0.208	0.237
Pb	0.453	0.385
Th	0.051	0.047
U	0.016	0.016

to estimate owing to the loss of volatiles that are less abundant in ordinary than in carbonaceous chondrites. The loss of volatiles can be as much as 75% of the original mass of a meteorite and even more for noble gases.[2] Low abundances of volatile elements are characteristic of ordinary chondrites.

Classification. The Thuathe meteorite proved to be an H-type ordinary chondrite, the classification of which was based on the atomic ratios Mg/Si, Fe/Si and Al/Si.[2] The petrological type of the meteorite was determined with the aid of the criteria of Wasson[4] and Dodd,[2] according to which the Thuathe meteorite belongs to the H4/5 type. Local shock melting was observed by means of optical microscopy, and the degree of shock was classified as S2–S3.[7]

Chemical analysis. The chemical composition of two stones indicated marked depletion of Zr, and enrichment in Rb, Th, Ta, Ba, La, Sr, Sc, Cr, Co and Ni, with respect to average chondrites (Fig. 4). The rare earth element spectrum is absolutely flat with no sign of LREE/HREE variation (Fig. 5). No Eu anomaly was detected.

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1. Ambrose D. (2003). *Catalogue of Stones from the Strewn Field of the Thuathe Meteorite of 21 July 2002.* House 9 Publications, Lesotho.
2. Dodd R.T. (1981). In *Meteorites, a Petrologic-chemical Synthesis,* pp. 1–27, 77–132. Cambridge University Press, Cambridge.
3. More T. and Green D.H. (1978). Laboratory duplication of phase equilibria observed in natural garnet lherzolites. *J. Geol.* **86**, 83–97.
4. Wasson J.T. (1974). In *Meteorites, Classification and Properties,* pp. 11–60. Springer-Verlag, Heidelberg.
5. Wood D.A., Tarney J., Varet J., Saunders A.D., Bougault H., Joron J.L., Treuil M. and Cann J.R. (1979). Geochemistry of basalts drilled in the North Atlantic by IPOD Leg 49: implications for mantle heterogeneity. *Earth Planet. Sci. Lett.* **42**, 77–97.
6. Sun S.S. (1982). Chemical composition and origin of the earth's primitive mantle. *Geochim. Cosmochim. Acta* **46**, 179–192.
7. Ambrose D.P., Reimold W.U. and Buchanan P.C. (2003). The Thuathe meteorite of 21 July 2002, Lesotho: mapping the strewn field and initial mineralogical classification. *S. Afr. J. Sci.* **99**, 153–159.

In Brief...

People

- The University of the Witwatersrand has appointed **Loyiso Nongxa** as vice-chancellor in succession to **Norma Reid Birley**, who resigned in November last year. Professor Nongxa is a graduate of the University of Fort Hare, and obtained a D.Phil. in mathematics at Oxford as the first African Rhodes Scholar from South Africa. Before being appointed deputy vice-chancellor for research at Wits in September 2000, he held a professorial position at the University of the Western Cape for ten years, during which period he was also dean of the Faculty of Natural Sciences.
- **Justin Jonas**, head of the Department of Physics and Electronics at Rhodes University, has been appointed managing director of the Hartebeesthoek Radio Astronomy Observatory (HartRAO), west of Pretoria, as successor to **George Nicolson**, who has retired after 43 years at the observatory. HartRAO is the oldest radio astronomy observatory in Africa and one of the National Facilities in the National Research Foundation family.
- The following young academics have been appointed to its category P (researchers who are recognized by the international community as prospective leaders in their fields) by the National Research Foundation: **Justin O'Riain** (Zoology, University of Cape Town), who works on behavioural ecology and evolution, focusing on meerkats and mole-rats; **David Spurrett** (Science Philosophy, University of Natal), whose research interests embrace cognitive science and cognitive development, linguistics, and human/computer interaction; and **Anton Fagan** (Private Law, University of Cape Town), whose specializations are legal philosophy, the law of delict, and constitutional theory.
- **Harold Annegarn** has been presented with the Group Achievement Award by the US National Aeronautics and Space Administration, in recognition of outstanding dedication and leadership in the execution of the Southern African Regional Science Initiative (SAFARI 2000) (see articles in the March/April 2002 issue of the *SAJS*). Professor Annegarn is in the School of Geosciences at the University of the Witwatersrand.
- **Jackie King**, principal research officer with the Freshwater Research Unit in the Zoology Department, University of Cape Town, is the recipient of an annual Women in Water Award, in the senior researcher category, from the minister of water affairs and forestry. Dr King is one of the main architects of methods for assessing how much water should be left in rivers to maintain their natural biophysical diversity, as well as an expert on the invertebrate communities in rivers.

News from the NRF

The National Research Foundation's *Guide to Research Support in 2004* is now available on the NRF website at http://www.nrf.ac.za/funding/guide/ The aim of the document is to enable researchers in the natural and social sciences, humanities, engineering and technology to explore the various research support programmes offered by the Research and Innovation Support Agency of the foundation.

Technikons with approved Research Niche Areas within the Technikon Research Development Programme are invited to apply for funding for 2004. The Programme Framework 2002–2007 and Manual for 2004 are available at http://www.nrf.ac.za/funding/guide/techintro.stm The URL for the online submission system for funding applications is http://submissions.nrf.ac.za