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FOREWORD

This document is a compilation of reports from Principal Investigators and their Associates of NASA's Office of Space Science, Solar System Exploration Division, Planetary Geology Program. The reports present research that adds to our knowledge of the origin and evaluation of the solar system and to our understanding of the earth as a planet. Advances in Planetary Geology was established as a complement to the abstract document "Reports of Planetary Geology Program" and to professional journals. This document provides a method of publishing research results which are in a form that would not normally be published elsewhere. The research reports may be in the form of lengthy research reports, progress reports, Ph.D. dissertations, or master's theses.

Joseph M. Boyce
Discipline Scientist
Planetary Geology Program
Office of Space Science

To Contributors:

A wider variety of manuscripts can be accommodated by *Advances in Planetary Geology* than by most journals. Particularly appropriate are complete theses, dissertations, and research reliant on extensive presentations of data. All contributions must be of direct interest to planetary geologists and must be of high quality. Manuscripts must be typed single spaced in a camera-ready format and sent to:

Alex Woronow
Lunar and Planetary Laboratory
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CONTENTS

SECTION I:

Catalog of Terrestrial Craterform Structures. Part 3, Northern Europe

J. L. Whitford-Stark

CATALOG
OF
TERRESTRIAL CRATERIFORM STRUCTURES

PART 3

NORTHERN EUROPE

Compiled by J.L.Whitford-Stark

GENERAL INTRODUCTION

The techniques of spacecraft photography have now advanced to a position where meaningful comparisons can be made between features of an equivalent size on the terrestrial planets and satellites. In practice this usually means craters or crateriform structures. The literature concerning terrestrial structures is the product of several disciplines, and accordingly is widely scattered in the literature. No single comprehensive body of information appears to exist in a form directly useful to planetary geologists. Catalogs of supposed impact structures have been compiled,for instance by Monod, and by O'Connell for the Rand Organization, and these are valuable though restricted in their terms of reference.

A certain need has been felt for a comprehensive, though not necessarily exhaustive, modern catalog listing craters irrespective of their mode of origin, to serve as a basis for the analysis of lunar and planetary photographs. This catalog is an attempt to satisfy that need. It is, therefore, aimed primarily at planetary geologists. Due to the constantly increasing volume of available information, this catalog will inevitably become rapidly out of date. Readers are encouraged to send any new information or corrections to the existing catalog to J.L.Whitford-Stark, for possible inclusion in any revised editions.

The catalog was originally published by the then ESRO, the first two parts being printed as Part 1 (Canada) and Part 2 (Indonesia) as ESRO SP-92 and SP-93 both being edited by R.J.Fryer. The original edition of this, Part 3, of the catalog was also edited by R.J.Fryer but, because of a policy change and name change to ESA, this volume was never printed but received limited circulation. In the four years since the original circulation of this catalog over 50 structures have been added. There has been no attempt to make any editorial comments on the interpretations of the various structures which are listed. The reader is referred to the referenced papers to make his or her own judgement as to the credibility of the various interpretations.

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INTRODUCTION - NORTHERN EUROPE

This catalog lists and describes some 150 features or groups of features which lie in northern Europe, and which are, or may well in the past have been, crateriform in appearance. Many of the features are "classic" examples of particular geological forms and have, as a result been described by many authors. It has therefore been the policy within this compilation, and for these features, to quote only reviews or classic papers. The reader will find leads to the general literature via these references.

The decision to limit the geographical coverage of this compilation to northern Europe (defined as Europe north of the Pyrenees, Alps, and Transylvanian Alps) was taken in order to restrict the task to one which might reasonably be undertaken by a single compiler within a reasonable time period. Southern Europe will form the subject of a subsequent section, hopefully in the not too distant future.

For each structure Section I presents basic data concerning its surface form and location; Section II a brief description of its form and structure (often quoted directly from a published account); Section III a summary of suggested modes of origin; and Section IV detailed reference to reports of specific studies. The studies to which the columns in section IV refer are:-

1. Aerial photography
2. Topographic map
3. Geologic map
4. Geologic section
5. Regional structure mapping
6. Gravitational anomaly mapping
7. Magnetic anomaly mapping
8. Topographic profile
9. Borehole studies
10. Reported shock metamorphism
11. Reported shatter coning
12. Blank

Geographical positions are given in degrees and minutes. Thus for the BARNSMORE PLUTON, 54.45N indicates that the feature lies at latitude 54° 45′ North.

Generally speaking, structures less than 500 m or less in diameter have been omitted; including the "Wiltshire Crater", the Knhynahinya Fall, and St.Sauver; all are found in other compilations. An exception to this rule was made only for those structures judged to be of unusual interest, or to draw attention to the existence of little known structures.

This section was prepared partly while the compiler held an N.E.R.C. grant at the Lunar and Planetary Unit, Department of Environmental Sciences, University of Lancaster, England, and partly under NASA grant NGR-40-002-116 at Brown University. Professors E.Rutte, C.Oftedahl, and W.E.Elston are gratefully acknowledged for their advice and information regarding specific features. R.J.Fryer inspired the author to compile this volume and acted as editor of the first edition. I would also like to thank Robert F. Austin,Chairman Geography Department,University of Missouri,Columbia, for the provision of office space.

J.L.Whitford-Stark

INDEX

The name under which the structure is listed is printed in CAPITALS. Alternative names are in lower case. The left hand column is alphabetic order.

	ALPHABETIC LISTING	LISTED UNDER
	Central,nyy Massif	TURYI
*	ČESKÉ BUDĚJOVICE	ČESKÉ BUDĚJOVICE
	CHAGVE-UAIV	CHAGVE-UAIV
*	CHAM DEPRESSION	CHAM DEPRESSION
*	Chassenon Crater	ROCHECHOUART
	Chibina Massif	KHIBINA MASSIF
	CISTA COMPLEX	CISTA COMPLEX
*	CONFOLENT	CONFOLENT
	Dagali-Holmen Breccia Pipe	HOLMEN-DAGALI BRECCIA PIPE
*	DELLEN STRUCTURE	DELLEN STRUCTURE
	DITRO COMPLEX	DITRO COMPLEX
	Doline of Soulanges	SOULANGES DOLINE
	DRAMMEN CAULDRON	DRAMMEN CAULDRON
	DREISER WEITHER BASIN	DREISER WEITHER BASIN
*	EDELBACH	EDELBACH
	ELETOZERO MASSIF	ELETOZERO MASSIF
	ETIVE GRANITE COMPLEX	ETIVE GRANITE COMPLEX
	FALKENSTEIN PIPE	FALKENSTEIN PIPE
*	Faugères Craters	HÉRAULT CRATERS
	FAULD CRATER	FAULD CRATER
	FEN COMPLEX	FEN COMPLEX
*	FIRTH DEEP	FIRTH DEEP
	FLAJE COMPLEX	FLAJE COMPLEX
	GARDNOS BRECCIA PIPE	GARDNOS BRECCIA PIPE
	GEMÜNDENERMAAR	GEMÜNDENERMAAR
*	GFÖHL	GFÖHL
	GJERDINGEN RING STRUCTURE	GJERDINGEN RING STRUCTURE
	GLEN COE CAULDRON	GLEN COE CAULDRON
	Glencoe Cauldron	GLEN COE CAULDRON
	GLITREVANN CAULDRON	GLITREVANN CAULDRON

	ALPHABETIC LISTING	LISTED UNDER
	GORNOOZERSK	GORNOOZERSK
	Gour de Tazenat	TAZENAT MAAR
	Gremjakha-Virmes Massif	GREMYATKLA-BYRMES MASSIF
	GREMYATKLA-BYRMES MASSIF	GREMYATKLA-BYRMES MASSIF
	GRUA CAULDRON	GRUA CAULDRON
*	GUSEV	GUSEV
	HEGGELIA CAULDRON	HEGGELIA CAULDRON
*	HEMAU	HEMAU
*	Hemauer Pulk	HEMAU
*	HÉRAULT	HÉRAULT
	HILLESTAD CALDERA	HILLESTAD CALDERA
	Hillestad Laccolith	HILLESTAD CALDERA
	HIRSCHBERG PIPE	HIRSCHBERG PIPE
	HOLMEN-DAGALI BRECCIA PIPE	HOLMEN-DAGALI BRECCIA PIPE
*	HUNGARIAN PLAIN	HUNGARIAN PLAIN
	HURDAL CAULDRON	HURDAL CAULDRON
	IIVAARA COMPLEX	IIVAARA COMPLEX
*	Il'inets	ILINTSY
*	Il'inetskaya	ILINTSY
*	ILINTSY	ILINTSY
*	Ilumetsa Craters	ILUMETS CRATERS
*	ILUMETS CRATERS	ILUMETS CRATERS
	INGOZERO MASSIF	INGOZERO MASSIF
*	JÄNISJÄRVI	JÄNISJÄRVI
*	JASENICE AMPHITHEATRE	JASENICE AMPHITHEATRE
	Jelettijarvi	ELETOZERO ?
	JUSI PIPE	JUSI PIPE
*	KAALIJARV CRATERS	KAALIJARV CRATERS
*	KALUGA	KALUGA
*	KAMENSK	KAMENSK

ALPHABETIC LISTING	LISTED UNDER
KAMPEN CAULDRON	KAMPEN CAULDRON
* KARLA	KARLA
KATNOSA RING COMPLEX	KATNOSA RING COMPLEX
KHIBINA MASSIF	KHIBINA MASSIF
KIKUT RING STRUCTURE	KIKUT RING STRUCTURE
* KJARDLA	KJARDLA
* KÖFELS	KÖFELS
KONTOZERO	KONTOZERO
Kontozersk	KONTOZERO
Koutajärvi	KOVDOZERO
Kouterojärvi	KOVDOR
KOVDOR	KOVDOR
Kovdorozero	KOVDOR
KOVDOZERO	KOVDOZERO
Kovdozersk	KOVDOZERO
Kuolo-jarvi	VUORIJARVI
KURGA	KURGA
Kurginskiy	KURGA
* KURSK	KURSK
LAACHER SEE	LAACHER SEE
* LAC BOUCHET	LAC BOUCHET
* Lac du Bouchet	LAC BOUCHET
Lachermaar	LAACHER SEE
* LAGO TREMORGIO	LAGO TREMORGIO
LAIVAJOKI	LAIVAJOKI
* Lake Dellen	DELLEN STRUCTURE
* LAKE HUMMELN	LAKE HUMMELN
LAKE LAATOKKA BASIN	LAKE LAATOKKA BASIN
Lake Ladozhskoye Oz	LAKE LAATOKKA BASIN
Lake Ladoga	LAKE LAATOKKA BASIN

ALPHABETIC LISTING	LISTED UNDER
* Lake Lappajärvi	LAPPAJÄRVI STRUCTURE
* LAKE MIEN	LAKE MIEN
LANGESUNDSFJORD CAULDRON	LANGESUNDSFJORD CAULDRON
LANGLIA RING STRUCTURE	LANGLIA RING STRUCTURE
Langlia-Storflaaten Area	SVARTEN CAULDRON
* LAPPAJÄRVI STRUCTURE	LAPPAJÄRVI STRUCTURE
* LA SAUVETAT	LA SAUVETAT
* Le Clot	HÉRAULT CRATERS
LESNAYA VARAKA	LESNAYA VARAKA
* LOGOISK	LOGOISK
LOVOZERO MASSIF	LOVOZERO MASSIF
Lujavrurt Massif	LOVOZERO MASSIF
LUNDBERGKOLLEN CAULDRON	LUNDBERGKOLLEN CAULDRON
MAVRGUBINSKY COMPLEX	MAVRGUBINSKY COMPLEX
MEERFELDER MAAR	MEERFELDER MAAR
* MENDORF	MENDORF
* Mienstrukturen	LAKE MIEN
* MISARAI	MISARAI
* MISHINA GORA	MISHINA GORA
* Mishinogorsk	MISHINA GORA
MOURNE GRANITE	MOURNE GRANITE
MULL COMPLEX	MULL COMPLEX
MYKLE RING STRUCTURE	MYKLE RING STRUCTURE
* NETOLICE EXPLOSION CRATER	NETOLICE EXPLOSION CRATER
NITTEDAL CAULDRON	NITTEDAL CAULDRON
NORDLIKAMPEN RING COMPLEX	NORDLIKAMPEN RING COMPLEX
* Nördlinger Ries	RIESKESSEL
* Norra Dellen	DELLEN STRUCTURE
NORRA KÄRR	NORRA KÄRR
* OBOLON'	OBOLON'

ALPHABETIC LISTING	LISTED UNDER
OPPKUVEN BRECCIA PIPE	OPPKUVEN BRECCIA PIPE
Oppkuven Cauldron	OPPKUVEN BRECCIA PIPE
* Oesel (Osel)	KAALIJARV CRATERS
ØYANGEN CAULDRON	ØYANGEN CAULDRON
Ozernaya Varaka	OZERNAYA VERAKA
OZERNAYA VERAKA	OZERNAYA VERAKA
PESOTCHNIY	PESOTCHNIY
* Pfahldorf	PFAHLDORF CRATERS
* Pfahldorf Basin	PFAHLDORF CRATERS
* PFAHLDORF CRATERS	PFAHLDORF CRATERS
* PÖSING-WETTERFELD DEPRESSION	PÖSING-WETTERFELD DEPRESSION
* PUCHEZH-KATUNKI	PUCHEZH-KATUNKI
PULVERMAAR	PULVERMAAR
* Pyrguhaud	ILUMETS CRATERS
* RADHOŠT' AMPHITHEATRE	RADHOŠT' AMPHITHEATRE
RAMNES CALDERA	RAMNES CALDERA
* RANDECKER MAAR	RANDECKER MAAR
RHUM COMPLEX	RHUM COMPLEX
* Ries Structure	RIESKESSEL
* RIESKESSEL	RIESKESSEL
* ROCHECHOUART	ROCHECHOUART
RÖDERN PIPE	RÖDERN PIPE
Rosses Centered Complex	ROSSES RING COMPLEX
Rosses Granite (Complex)	ROSSES RING COMPLEX
Rosses Pluton	ROSSES RING COMPLEX
ROSSES RING COMPLEX	ROSSES RING COMPLEX
* ROTMISTROVKA	ROTMISTROVKA
* RÖTZ-WINKLARN DEPRESSION	RÖTZ-WINKLARN DEPRESSION
Rum	RHUM COMPLEX
Rundevatn	RUNDVATNET

	ALPHABETIC LISTING	LISTED UNDER
*	Rundevatnet	RUNDVATNET
*	RUNDVATNET	RUNDVATNET
*	SÄÄKSJÄRVI	SÄÄKSJÄRVI
*	SAAL	SAAL
	ST.HIPPOLYTE MAAR	ST.HIPPOLYTE MAAR
	ST.KILDA-SOAY-BORERAY-LEVENISH-DUN COMPLEX	ST.KILDA-SOAY-BORERAY-LEVENISH-DUN
*	ST.MAGNUS BAY DEEP	ST.MAGNUS BAY DEEP
	Salanlatvinsky	SALLANLATVI
	SALLANLATVI	SALLANLATVI
*	Sall Craters	KAALIJARV CRATERS
	Salmagorsky	SALMOGORSK MASSIF
	SALMOGORSK MASSIF	SALMOGORSK MASSIF
	SANDE CAULDRON	SANDE CAULDRON
	Sandelakkolith	SANDE CAULDRON
*	SAUSTAHL	SAUSTAHL
*	SCHAFFERGRUBE	SCHAFFERGRUBE
*	SCHAFGRABEN	SCHAFGRABEN
	SEBLJAVRSK MASSIF	SEBLJAVRSK MASSIF
	Sebl'yavr	SEBLJAVRSK MASSIF
	Sebl-yarvi	SEBLJAVRSK MASSIF
	SENĚZE MAAR	SENĚZE MAAR
*	SILJAN RING	SILJAN RING
	SKREHELLE CAULDRON	SKREHELLE CAULDRON
	SKYE COMPLEX	SKYE COMPLEX
	SLIEVE GULLION COMPLEX	SLIEVE GULLION COMPLEX
	SLOTTET RING STRUCTURE	SLOTTET RING STRUCTURE
	SNOWDON SYNCLINE	SNOWDON SYNCLINE
*	Söderfjärden Basin	VAASA STRUCTURE
*	Sodra Dellen	DELLEN STRUCTURE
	SOKLI	SOKLI

ALPHABETIC LISTING	LISTED UNDER
* Sornhüll	PFAHLDORF CRATERS
SØRØY	SØRØY
SOULANGES DOLINE	SOULANGES DOLINE
SOUSTOVA MASSIF	SOUSTOVA MASSIF
Soustovsk Massif	SOUSTOVA MASSIF
* STAMSRIED-PEMFLING-KATZBACH DEPRESSION	STAMSRIED-PEMFLING-KATZBACH DEPRESSION
* STEINHEIM BASIN	STEINHEIM BASIN
* Steinheimer Becken	STEINHEIM BASIN
STENOVICE COMPLEX	STENOVICE COMPLEX
* STOPFENHEIM KUPPEL	STOPFENHEIM KUPPEL
STRYKEN CAULDRON	STRYKEN CAULDRON
* Süvahaud	ILUMETS CRATERS
SVARTEN CAULDRON	SVARTEN CAULDRON
TAZENAT MAAR	TAZENAT MAAR
* TIEFENBACH-SCHÖNTHAL DEPRESSION	TIEFENBACH-SCHÖNTHAL DEPRESSION
* TŘEBOŇ	TŘEBOŇ
TRYVASSHØGDA RING COMPLEX	TRYVASSHØGDA RING COMPLEX
Tsagve-Oaivi	CHAGVE-UAIV
Turii, Turja, Turyii	TURYI
TURYI	TURYI
* TVÄREN BAY	TVÄREN BAY
Umptek Massif	KHIBINA MASSIF
* VAASA STRUCTURE	VAASA STRUCTURE
VEALØS CAULDRON	VEALØS CAULDRON
* VEPRIAJ	VEPRIAJ
VUORIJARVI MASSIF	VUORIJARVI MASSIF
Vuoriyarvi	VUORIJARVI MASSIF
WEINFELDER MAAR	WEINFELDER MAAR
* WIPFELSFURT	WIPFELSFURT
* Yanis'yarvi	JÄNISJÄRVI

ALPHABETIC LISTING	LISTED UNDER
Yelet'ozero	ELETOZERO MASSIF
* ZELENY GAI	ZELENY GAI

* Denotes structures which have been ascribed a possible,probable, or definite origin by impact.

I. BASIC DATA

Name	**AFRIKANDA** massif	
Alternative names		
Location	Kola Peninsula, USSR	
Geographical position	67.00N 32.00E	*after Gerasimovsky et al,1974*
Horizontal dimensions	Approx. 8 x 6 km 7 km^2	*after Gerasimovsky et al,1974* *Heinrich, 1966*
Depth		
Altitude		
Rim		
Age	Caledonian 344 - 426 m.y.	*Gersimovsky et al, 1974* *Vartiainen & Wooley,1974*

II.FORM AND STRUCTURE

Outer ring pyroxenites and melteigites. Centrally the pyroxenites become first fine grained and next coarse grained, with schleiren and veins of titanomagnetite-knopite rock. The core is an eruptive breccia of melilite olivinite in a cement of coarse pyroxenite and vibetoite.

Heinrich, 1966

III.ORIGIN

Astrobleme

Non astrobleme

Alkaline intrusion

Gerasimovsky et al, 1974
Heinrich, 1966

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**ALMUNGE**	
Alternative names		
Location	18 miles east of Uppsala, Sweden	
Geographical position	59.52N 18.06E	*after Gorbatschev,1961*
Horizontal dimensions	15 km^2, about 3 x 5 km	*Gorbatschev, 1961*
Depth		
Altitude		
Rim		
Age	1580 m.y.	*Vartiainen & Wooley,1974*

II.FORM AND STRUCTURE

Irregularly rounded area surrounded by Svecofennian Archean supracrustals. Nepheline-bearing rocks....joining in an obvious ring of comparatively small, mostly schistose en-echelon dikes, encompassing nearly all of the western, southern and northern peripheries of the alkali area.

Gorbatschev, 1961

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Gorbatschev, 1961

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Gorbatschev, 1961

I. BASIC DATA

Name	**ALNÖ**	
Alternative names		
Location	Baltic, NE. of Sundsvall, Sweden	
Geographical position	62.28N 17.30E	*von Eckermann et al,1960*
Horizontal dimensions	8 km^2 of NE. of Island:Center under sea 4 km diameter, Cone sheets to 12 km from core, dikes to 25 km	*von Eckermann et al,1960*
Depth		
Altitude		
Rim		
Age	562 m.y. 537 ± 16 m.y.	*von Eckermann et al,1960* *Krester et al, 1977*

II.FORM AND STRUCTURE

"Carbonatite dikes....indicate the dip of cone-sheets towards the volcanic center north of Alnö Island."

von Eckermann et al, 1960

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

von Eckermann et al,1960

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

von Eckermann et al, 1960

I. BASIC DATA

Name	**ALNSJØ CAULDRON**	
Alternative names		
Location	Southeastern Norway	
Geographical position	59.30N 11.00E	*after Oftedahl,I969*
Horizontal dimensions	Diameter 15km (?)	*Oftedahl,I960*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Oftedahl,I960*

II. FORM AND STRUCTURE

Eroded remnant of a block which suffered cauldron subsidence of the order of 1.5 to 2.0km.

Oftedahl,I960

III. ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl,I960

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**ARDNAMURCHAN RING COMPLEX**	
Alternative names		
Location	A peninsula on the west coast of Scotland	
Geographical position	56.40N 6.10W	*after Richey et al, I96I*
Horizontal dimensions	15 x 7.4km within sea-eroded edges	*Richey et al, I96I*
Depth		
Altitude		
Rim		
Age	Tertiary Dykes $26 \pm 4 \times 10^6$, Minor intrusions $55 \pm 6 \times 10^6$	*Richey et al, I96I* *Evans et al, I973*

II. FORM AND STRUCTURE

A series of ring complexes related to one centre (*Durrance, I967*) or to three centres (*Richey et al, I96I*).

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion and extrusion.

Richey et al, I96I
Craig, I965
Durrance, I967

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●								*Richey et al, I96I*
●		●		●								*Craig, I965*

I. BASIC DATA

Name	**ARRAN CENTRAL RING COMPLEX**	
Alternative names		
Location	Island in the Firth of Clyde, west Scotland	
Geographical position	55.35N 5.15W	*after Richey et al, I96I*
Horizontal dimensions	Approximately 5km diameter 5.4 x 4.8km (4 x 3 miles)	*Richey et al, I96I* *King, I954*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Tertiary Granite = $61\pm6, 65\pm6, 55\pm5, 56\pm5, 57\pm6, 63\pm6, 60\pm6, 62\pm6$; Minor intrusions $61\pm6 \times 10^6$yrs $58.3\pm2.2 \times 10^6$yrs	*Richey et al, I96I* *Miller & Mohn, I965* *quoted by* *Evans et al, I973*

II. FORM AND STRUCTURE

Eroded remains of a block of sedimentary rocks and lavas that subsided 3,000 feet (920m).

King, I954

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion and extrusion
King, I954

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●	●	●	●								*King, I954*
		●										*Richey et al, I96I*

I. BASIC DATA

Name	**ȦVA** complex	
Alternative names	Angskarsfjarden	
Location	Northeastern Aland Isalands,Finland	
Geographical position		
Horizontal dimensions	Central ring 5.5 km diameter	*Kaitaro, 1953*
Depth	20 m or more	*Kaitaro, 1953*
Altitude		
Rim		
Age	1830 m.y.	*Neuvonen, 1970*

II.FORM AND STRUCTURE

More than 50 radial lamprophyric dikes. Arcuate concentric sheets of granitic ring intrusions. Radiating fracture system.

kaitaro, 1953

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Kaitaro,1953

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Kaitaro, 1953

I. BASIC DATA

Name	**BAERUM** cauldron	
Alternative names	Baerumlakkolith Baerum - Sørkedal Cauldron	
Location	Near Oslo, Norway	
Geographical position	60.00N 10.30E	*after Oftedahl, 1969*
Horizontal dimensions	12 x 8.5 km	*Oftedahl, 1953*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Oftedahl, 1953*

II.FORM AND STRUCTURE

"A cylindrical block of lavas with a thick sill-like intrusion and smaller irregular intrusions of monzonitic-syenitic,fine-grained rocks subsided into a syenitic magma along a ring fault, which was invaded by the magma to form a nearly complete ring dyke." Subsidence 1.0 to 1.5 km.

Oftedahl, 1953

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Oftedahl, 1953

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●								*Oftedahl, 1953*
				●								*Ramberg 1976*

I. BASIC DATA

Name — **BARNSMORE PLUTON**

Alternative names — Barnsmore Granite (Complex)

Location — Donegal, Eire

Geographical position — 54.45N 8.00W — *after Pitcher & Berger, I972*

Horizontal dimensions — Original structure offset by faulting, was approximately 11 x 5km($52km^2$) — *Pitcher & Berger, I972*

Depth

Altitude

Rim

Age — Caledonian — *Pitcher & Berger, I972*

II. FORM AND STRUCTURE

Elongate complex of three sharply defined granites. Outer dip 50 to 90 degrees, thickness 5.6km.

Pitcher & Berger, I972

III. ORIGIN

Astrobleme

Non astrobleme

Subsidence of a large block of schists, perhaps along a ring dyke.

Walker & Leedal, I954

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		•	•									*Walker & Leedal, I954*
					•							*Riddihough, I969*
		•	•	•	•							*Pitcher & Berger, I972*

I. BASIC DATA

Name	**BEAUNIT**	
Alternative names		
Location	Auvergne,France	
Geographical position	45.58N 2.56E	*after Baudry & Camus,I970*
Horizontal dimensions	Approximate diameter 1.0km	*Baudry & Camus,I970*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"Situé dans la partie nord de la chaîne,cet appareil est le plus important de ceux étudiés, l'emplacement de sa bouche d'émission,dont le diamètre est de l'ordre de 1km,est occupé par des terrains marécageux sur un substratum d'argiles lacustres.Ces formations détritiques sont partiellement recouvertes par des coulées venues du Sud et par un cone "strombolien" récent."

Baudry & Camus,I970

III. ORIGIN

Astrobleme

Non astrobleme

Maar

Baudry & Camus,I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Baudry & Camus,I970

I. BASIC DATA

Name	**BEN NEVIS COMPLEX**	
Alternative names		
Location	Inverness,Scotland	
Geographical position	56.48N 6.00W	*after Bailey et al,I9I5*
Horizontal dimensions	Diameter 6km	*Bailey et al,I9I5*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Lower Old Red Sandstone	*Bailey et al,I9I5*

II. FORM AND STRUCTURE

Ring complex of granitic intrusive rocks and andesitic extrusives with +1,500 feet(460m) subsidence along a fault block.

Bailey et al,I9I5

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion

Bailey et al,I9I5

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	•	•	•	•							

Bailey et al,I9I5

I. BASIC DATA

Name	**BIRNBERG PIPE**	
Alternative names		
Location	Saar-Nahe Trough, SW. Germany	
Geographical position		
Horizontal dimensions	Long diameter 1.22km	*Lorenz et al, I970*
Depth		
Altitude		
Rim		
Age	Permian	*Lorenz et al, I970*

II. FORM AND STRUCTURE

"...stratified, subsided pyroclastic beds are found near the margins of the pipe whereas the central part is occupied by intrusive andesite."

Lorenz et al, I970

III. ORIGIN

Astrobleme

Non astrobleme

Diatreme

Lorenz et al, I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		•									

Lorenz et al, I970

I. BASIC DATA

Name	**BJØRNSJØEN** ring complex	
Alternative names		
Location	Norway	
Geographical position	60.00N 10.45E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 7 - 9 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Basic center to syenitic outer zone.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**BOLTYSH**	
Alternative names	Boltyshka	
Location	Ukranian SSR, USSR	
Geographical position	48.45N 32.10E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 25 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	100 ± 5 m.y. about 70 m.y. Late Cretaceous - Early Jurassic	*Grieve & Robertson, 1979* *Masaytis 1975* *Yurk et al, 1975*

II.FORM AND STRUCTURE

"Base of buried crater lies approximately 1 km below the surface of the Precambrian basement. In the center of the crater is an uplift of crushed, cataclased and partially fused granites, 2 x 4 km in size, with a relative height of about 500 m above the base.

Masaytis, 1975

III.ORIGIN

Astrobleme

Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●					●	●		

Masaytis, 1975

I. BASIC DATA

Name	**BOOS MAARS**	
Alternative names		
Location	Eiffel,West Germany	
Geographical position		
Horizontal dimensions	Diameter 650 to 700m	*Lorenz,1973*
Depth	30 to 87m	*Lorenz,1973*
Altitude		
Rim		
Age	Pleistocene	*Lorenz,1973*

II. FORM AND STRUCTURE

"The two maars are associated with a number of other volcanic features...To the E and NE there are four cinder cones on top of the hill(Schneeberg). At the E slope of the E maar a 4-7m wide alkali basaltic dyke trends ENE.The two maars, cut into Lower Devonian slates,sandstones, and greywackes,are located at the bottom of a valley which today contains a very small stream."

Lorenz,1973

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic

Lorenz,1973

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Lorenz,1973

I. BASIC DATA

Name	**BORROLAN** complex	
Alternative names	Borralon complex	
Location	N.W.Scotland, across border of Ross & Cromarty & Sutherland	
Geographical position	58.08N 5.00W	
Horizontal dimensions	6.5 x 3.5 km	*after Wooley, 1970*
Depth		
Altitude		
Rim		
Age	388 m.y.	*Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

"The overall picture, therefore, is of an outer, composite, conformable sheet gradually thickening inwards which is cut by a much thicker syenite body. It would seem that although the intrusion has a laccolithic shape, because of its composite nature it cannot be strictly classified as a laccolith."

Wooley, 1970

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Wooley, 1970

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●								

Wooley, 1970

I. BASIC DATA

Name	**CARLINGFORD COMPLEX**	
Alternative names		
Location	Louth, Eire	
Geographical position	54.03N 6.15W	*after Charlesworth, I963*
Horizontal dimensions	Diameter 9.6km(6 miles)	*Charlesworth, I963*
Depth		
Altitude		
Rim		
Age	Tertiary 58.5×10^6 yrs	*Charlesworth, I963* *Evans et al, I973*

II. FORM AND STRUCTURE

Ring complex of gabbros, dolerites, basalts, granophyres, and agglomerates containing nine vents of 105 to 610m diameter and cone sheets dipping at 60 degrees.

Charlesworth, I963

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion

Charlesworth, I963

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
					●							*Cook & Murphy, I952*
		●	●	●	●							*Charlesworth, I963*

I. BASIC DATA

Name ČESKÉ BUDĚJOVICE

Alternative names

Location Czechoslovakia

Geographical position 49.00N 14.30E *after Rutte,1974*

Horizontal dimensions

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

"Kraterlandschaft with shocked minerals"

Rutte,1974

III. ORIGIN

Astrobleme

Rutte,1974

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Rutte,1974

I. BASIC DATA

Name	**CHAGVE - UAIV**	
Alternative names	Tsagve-Oaivi	
Location	North Kola Peninsula, USSR	
Geographical position		
Horizontal dimensions	1.5 x 1.0 km	*Tomkeieff, 1961*
Depth		
Altitude		
Rim		
Age		

II.FORM AND STRUCTURE

Oval shaped massif in plan. Steeply dipping layered complex. Three intrusive phases can be distinguished.

Tomkeieff,1961

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Tomkeieff, 1961

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**CHAM DEPRESSION**	
Alternative names		
Location	West Germany	
Geographical position	49.14N 12.37E	*Classen,1975*
Horizontal dimensions	Diameter about 1km	*Classen,1975*
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen,1975*

II. FORM AND STRUCTURE

Depression of many craters.

Classen,1975

(see also PÖSING-WETTERFELD and STAMSRIED-PEMFLING-KATZBACH depressions)

III. ORIGIN

Astrobleme

Classen,1975

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**CISTA** complex	
Alternative names		
Location	Czechoslovakia	
Geographical position	50.02N 13.35E	
Horizontal dimensions	12 x 8 km	*Bartosek et al, 1969*
Depth		
Altitude		
Rim		
Age	310 ± 10 m.y.	*Bartosek et al,1969*

II.FORM AND STRUCTURE

Central stock of granodiorite with foliated marginal facies. Bordering intrusions of biotite granite.

Bartosek et al, 1969

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Bartosek et al, 1969

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**CONFOLENT**	
Alternative names		
Location	Haute-Loire, France	
Geographical position		
Horizontal dimensions	Diameter approximately 1.5km	*Gallant, I964*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"meandre abandonné avec au centre une butte de roche en place."

A. Cailleux in Monod, I965

III. ORIGIN

Astrobleme

? *Gallant, I964*

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**DELLEN STRUCTURE**	
Alternative names	Lake Dellen Norra Dellen and Sodra Dellen	
Location	300km NNW of Stockholm, Sweden	
Geographical position	61.50N 16.45E 61.55N 16.32E	*v.Engelhardt,1972* *Fredriksson & Wickman,1963*
Horizontal dimensions	Original diameter 15km	*v.Engelhardt,1972*
Depth		
Altitude		
Rim		
Age	50 to 200 x 10^6 yrs Lower Tertiary	*Fredriksson & Wickman,1963* *Bylund,1974*

II. FORM AND STRUCTURE

Deeply eroded structure of two lakes separated by a peninsula.

v.Engelhardt,1972

III. ORIGIN

Astrobleme

Fredriksson & Wickman,1963
Carstens,1975

Non astrobleme

Glacial excavation of a region shattered by volcanic explosions.

Eskola,1921

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Carstens,1975

I. BASIC DATA

Name **DITRO** complex

Alternative names

Location Eastern Carpathians, Roumania

Geographical position 46.48N 25.30E *Streckeisen, 1960*

Horizontal dimensions 14 x 19 km, 170 km^2 *Streckeisen, 1960*

Depth

Altitude

Rim

Age post pre-Permian,pre-Pliocene,
probably Lower Cretaceaous or Upper Lias
to Lower Dogger.
Streckeisen, 1960

II.FORM AND STRUCTURE

Elliptical form with some irregular excavations. The contacts with the country rocks are generally vertical or steep toward the outside, resulting in the impression of a circular or elliptical vent. The massif presents a distinct ring structure. It is formed by an outer ring, an intermediate ring and a central stock. The central stock has a circular surface of 6 km diameter.

Streckeisen, 1960

III.ORIGIN

Astrobleme

Non astrobleme
Intrusion
Streckeisen, 1960

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Streckeisen, 1960

I. BASIC DATA

Name	**DRAMMEN** Cauldron	
Alternative names		
Location	Around the city of Drammen,Norway	
Geographical position	59.45N 10.15E	*after Oftedahl, 1969*
Horizontal dimensions	Diameter 7 km	*Oftedahl, 1953*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1953*

II.FORM AND STRUCTURE

Block subsidence of the order of 500 m.

Oftedahl, 1953

"The subsidence of the lava block produced a bowl-shaped or saucer-shaped basin with a marginal upbending of the peripheral lavas."

Oftedahl, 1960

The subsidence of the central part of the cauldron may amount to around 1000 m.

oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1953
Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●								*Oftedahl, 1953*
				●		●						*Segalstad, 1975*
		●	●	●	●							*Ramberg, 1976*
		●		●								*Oftedahl, 1978*

I. BASIC DATA

Name	**DREISER WEITHER BASIN**	
Alternative names		
Location	Eiffel,West Germany	
Geographical position	50.15N 6.48E	*after Lorenz et al,1970*
Horizontal dimensions	1.36 x 1.18km	*Lorenz et al,1970*
Depth	36 to 120m	*Lorenz et al,1970*
Altitude		
Rim		
Age	10 to 12.5 x 10^3yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

"The fact that the volume of the pyroclastic deposits is much less than that of the basin indicates subsidence of a central block.Drilling holes near the centre revealed Devonian rocks under a thin pyroclastic cover."

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic eruption plus basin subsidence

Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●				●					

Lorenz et al,1970

I. BASIC DATA

Name **EDELBACH**

Alternative names

Location Austria

Geographical position 48.40N 15.28E *after Kutte,1974*

Horizontal dimensions

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

"Kraterlandschaft with shocked minerals."

Kutte,1974

III. ORIGIN

Astrobleme

Comet impact

Kutte,1974

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Kutte,1974

I. BASIC DATA

Name	**ELETOZERO** massif	
Alternative names	Yelet'ozero	
Location	USSR	
Geographical position	66.00N 32.00E	
Horizontal dimensions	50 km^2	*Gerasimovsky et al, 1974*
Depth		
Altitude		
Rim		
Age	1800 m.y.	*Vartiainen & Wooley,1974*

II.FORM AND STRUCTURE

It is of elliptical shape and is concentrically zoned, formed in three intrusive phases.

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●								

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**ETIVE GRANITE COMPLEX**	
Alternative names		
Location	Argyll, Scotland	
Geographical position	56.34N 5.00W	*after Anderson, 1937*
Horizontal dimensions	28 x 16km(18 x 10 miles)	*Anderson, 1937*
Depth		
Altitude	-	
Rim		
Age	Lower Old Red Sandstone	*Anderson, 1937*

II. FORM AND STRUCTURE

Ring complex of four granitic members - the Quarry Intrusion, the Cruachan Granite, the Meall Odhar Granite, and the Starav Granite.
Anderson, 1937

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion
Anderson, 1937
Bailey et al, 1960

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		•	•	•								*Anderson, 1937*
	•	•	•	•								*Bailey et al, 1960*

I. BASIC DATA

Name	**FALKENSTEIN PIPE**	
Alternative names		
Location	Saar-Nahe Trough,SW.Germany	
Geographical position		
Horizontal dimensions	Long diameter 1.52km	*Lorenz et al,1970*
Depth		
Altitude		
Rim		
Age	Permian	*Lorenz et al,1970*

II. FORM AND STRUCTURE

"Bedding in the pyroclastic ejecta and subsided blocks of sediments are mostly orientated toward the center of the structure."

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Diatreme
Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Lorenz et al,1970

I. BASIC DATA

Name	**FAULD CRATER**	
Alternative names	Burton-on-Trent Explosion Crater	
Location	Fauld, near Burton-on-Trent, England	
Geographical position	52.40N 1.35W	*Fielder & Guest, 1967*
Horizontal dimensions	Diameter 220 x 270m Diameter 240m	*Fielder & Guest, 1967* *Sharp, 1970*
Depth	See ORIGIN	
Altitude	See ORIGIN	
Rim	See ORIGIN	
Age	AD 1944	*Fielder & Guest, 1967*

II. FORM AND STRUCTURE

See ORIGIN

III. ORIGIN

Astrobleme

Non astrobleme

Explosion of 5.34×10^6 lbs of T.N.T. in an old alabaster mine producing a crater of ellipticity 18.5%.

Fielder & Guest, 1967

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
●												*Fielder & Guest, 1967*

I. BASIC DATA

Name	**FEN** complex	
Alternative names		
Location	southern Norway	
Geographical position	59.10N 9.30E	
Horizontal dimensions	5 km diameter	*Barth & Ramberg, 1966*
Depth		
Altitude		
Rim		
Age	565 m.y.	*Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

Vent filled with a suite of peralkaline igneous rocks, carbonatites and mixed silicate, carbonate rocks situated on a system of faults parallel to the western border of the Oslo graben.

Barth & Ramberg, 1966

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Barth & Ramberg, 1966

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Barth & Ramberg, 1966

I. BASIC DATA

Name	**FIRTH DEEP**	
Alternative names		
Location	Shetland Islands, 160km N. of Scottish mainland	
Geographical position	60.28N 0.58W	*Flinn,1970*
Horizontal dimensions		
Depth	Submarine 146m (80 fathoms)	*Flinn,1970*
Altitude		
Rim		
Age	Late Tertiary	*Flinn,1970*

II. FORM AND STRUCTURE

"Overdeep" elongate depression in a bay
Flinn,1970

(see also ST.MAGNUS BAY DEEP)

III. ORIGIN

Astrobleme

? *Flinn,1970*

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●											*Flinn,1970*

I. BASIC DATA

Name	**FLAJE** complex	
Alternative names		
Location	Czechoslovakia	
Geographical position		
Horizontal dimensions	Approx. 6 x 7 km	*Bartosek et al, 1969*
Depth		
Altitude		
Rim		
Age	307 ± 10 m.y.	*Bartosek et al, 1969*

II.FORM AND STRUCTURE

Central stock of biotite granite, approximately circular but with southerly protuberance.

Bartosek et al, 1969

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Bartosek et al, 1969

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**GARDNOS BRECCIA PIPE**	
Alternative names		
Location	90km NW. of Tyrifjord,Norway	
Geographical position		
Horizontal dimensions	Diameter approximately 4km	*Oftedahl,1960*
Depth		
Altitude		
Rim		
Age	Post Ordovician, probably Permian	*Oftedahl,1960*

II. FORM AND STRUCTURE

Breccia pipe consisting of angular fragments from dust to 50m in a black matrix. The fragments are largely derived from adjacent Precambrian rocks.

Oftedahl,1960

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic gas explosion

Brock quoted in Oftedahl,1960

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**GEMÜNDENERMAAR**	
Alternative names		
Location	Eiffel, West Germany	
Geographical position		
Horizontal dimensions	570 x 560m	*Lorenz et al,1970*
Depth	204m 53 to 154m	*Ollier,1967* *Lorenz et al,1970*
Altitude		
Rim		
Age	10.5 to 11.0 x 10^3yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

Funnel with a flat-bottomed floor.
Ollier,1967

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic
Ollier,1967
Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	●	●	●				●				

Lorenz et al,1970

First edition - 1976

I. BASIC DATA

Name GFÖHL

Alternative names

Location Austria

Geographical position 48.32N 15.30E *after Rutte,1974*

Horizontal dimensions

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

"Kraterlandschaft with shocked minerals."
Rutte,1974

III. ORIGIN

Astrobleme

Comet impact
Rutte,1974

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Rutte,1974

I. BASIC DATA

Name	**GJERDINGEN** ring structure	
Alternative names		
Location	30 km NNW of Oslo, Norway	
Geographical position	60.12N 10.35E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 4 - 5 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Basic center to syenitic or granitic outer zone.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●				●	●					*Kristoffersen, 1973*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name	**GLEN COE CAULDRON**	
Alternative names	Glencoe Cauldron	
Location	Argyll,Scotland	
Geographical position	56.40N 4.58W	*after Bailey et al,I9I5*
Horizontal dimensions	14.4 x 8km (9 x 5 miles)	*Bailey et al,I9I5*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Lower Old Red Sandstone	*Bailey et al,I9I5*

II. FORM AND STRUCTURE

"The area....is surrounded for four-fifths of its circumference by a fault which throws down the volcanic rocks and the underlying schists some thousands of feet."
Bailey et al,I9I5

Fault dip 50 to 70 degrees
Bailey et al,I960

Fault dip inward at 80 degrees
Taubeneck,I967

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion and extrusion
Bailey et al,I9I5
Taubeneck,I967

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	●	●	●	●							

Bailey et al,I9I5

I. BASIC DATA

Name	**GLITREVANN** Cauldron	
Alternative names		
Location	40 km west of Oslo, Norway	
Geographical position	59.47N 10.12E	*after Oftedahl, 1960*
Horizontal dimensions	16 x 10 km	*Oftedahl, 1953*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1953*

II.FORM AND STRUCTURE

"A cylindrical block subsided along a ring fault."
Subsidence 1500 m. *Oftedahl, 1953*

"..two ring faults, a nearly circular one and another in the southern sector south of the first."

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Oftedahl, 1953
Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●								*Oftedahl, 1953*
				●		●						*Segalstad, 1975*
		●	●	●	●							*Ramberg, 1976*
		●		●								*Oftedahl, 1978*

I. BASIC DATA

Name	**GORNOOZERSK**	
Alternative names		
Location	Kola Peninsula, USSR	
Geographical position		
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	392 to 540 m.y.	*Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Vartiainen & Wooley,1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**GREMYATKLA-BYRMES** massif	
Alternative names	Gremjakha-Virmes massif	
Location	NW Kola Peninsula, USSR	
Geographical position	68.40N 32.30E	
Horizontal dimensions	130 km^2 20 x 6 km	*Gerasimovsky et al, 1974* *Tomkeieff, 1961*
Depth		
Altitude		
Rim		
Age	1750 - 1870 m.y.	*Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

Three intrusive phases. The most abundant are rocks of the first intrusive phase mainly consisting of varieties of gabbro. The second intrusive phase forms a steeply dipping body in the central part of the massif and is dominated by foyaite. The third intrusive phase is composed of alkali granite, nordmarkite and, rarely, alkali syenite.

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**GRUA** cauldron	
Alternative names		
Location	West of Grua railway station, Norway	
Geographical position	60.15N 10.40E	*after Oftedal, 1978*
Horizontal dimensions	Diameter 5 km ?	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**GUSEV**	
Alternative names		
Location	USSR.	
Geographical position	48.20N 40.15E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 3 km	*Masaytis, 1975*
Depth		
Altitude		
Rim		
Age	65 m.y.	*Masaytis, 1975*

II.FORM AND STRUCTURE

Ellipsoidal basin about 400 m deep, filled with a breccia. The outlines have been controlled by the superimposition of subsequent tectonic movements and by uneven erosion.

Masaytis, 1975

III.ORIGIN

Astrobleme

Probably

Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●								

Masaytis, 1975

I. BASIC DATA

Name	**HEGGELIA** Cauldron	
Alternative names		
Location	NW. of Oslo, Norway	
Geographical position	60.04N 10.28E	*after Segalstad, 1975*
Horizontal dimensions	diameter 7 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

Subsidence 1.0 - 1.5 km

Oftedahl,1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Segalstad, 1975*
		●										*Oftedahl, 1978*

I. BASIC DATA

Name	**HEMAU**	
Alternative names	Hemauer Pulk	
Location	SW.Germany	
Geographical position	49.03N 11.47E	*Classen,I975*
Horizontal dimensions	30 craters in area of 8 x 12km Diameter 2.0km	*Rutte,I974* *Classen,I975*
Depth	100m to fill,more than 130m to the base of the fill	*Rutte,I97I*
Altitude	480m to top of infilling,600m to rim	*Rutte,I97I*
Rim	Height 20m (approx.)	*Rutte,I974*
Age	14.8×10^6yrs ?	*Classen,I975*

II. FORM AND STRUCTURE

14 craters
Classen,I975

30 craters
Rutte,I974

III. ORIGIN

Astrobleme

Comet impact
Rutte,I97I

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●		●	●					●			*Rutte,I97I*

I. BASIC DATA

Name	**HÉRAULT**	
Alternative names	Faugères Craters Cabrerolles (Le Clot)	
Location	Hérault District, S.France	
Geographical position	43.32N 3.08E	*O'Connell,1965*
Horizontal dimensions	Faugères 50 to 60m	*Gèze & Cailleux,1950*
	Le Clot 200-220m(enciente),100-110m(fond)	" " "
	No.1 65 to 80m	" " "
	No.2 50 to 65m	" " "
	No.3 45 to 50m	" " "
	No.4 15m	" " "
Depth	Faugères 23m	*Gèze & Cailleux,1950*
	Le Clot 50m	" " "
	No.1 28m	" " "
	No.2 20m	" " "
	No.3 9m	" " "
	No.4 5m	" " "
Altitude	Le Clot 295m	*Gèze & Cailleux,1950*
Rim	Le Clot, none	*Beals,1964*
Age	Quaternary to Recent	*Gèze & Cailleux,1950*

II. FORM AND STRUCTURE

Six, maybe seven, craters with strong magnetic anomalies in alumino-silicate rocks.

Gèze & Cailleux,1950

III. ORIGIN

Astrobleme

Gèze & Cailleux,1950

Uncertain on the basis of present evidence.

Beals,1964

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●											*Gèze & Cailleux,1950*

I. BASIC DATA

Name	**HILLESTAD** Caldera	
Alternative names	Hillestad laccolith	
Location	60 km SW. of Oslo, Norway	
Geographical position	59.38N 10.13E	*after Oftedahl, 1969*
Horizontal dimensions	Approximately 10 km diameter 5 km diameter	*Oftedahl, 1969* *Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Partly destroyed by a younger granite-syenite intrusion. *Oftedahl, 1969*

Strongly welded caldera-filling ignimbrite with a thickness of more than 300 m. Subsidence in excess of 500 m.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1969
Segalstad, 1975
Ramberg,1976

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●		●						*Segalstad, 1975*
		●	●	●	●							*Ramberg, 1976*
		●		●								*Oftedahl, 1978*

I. BASIC DATA

Name	**HIRSCHBERG PIPE**	
Alternative names		
Location	Saar-Nahe Trough,SW.Germany	
Geographical position		
Horizontal dimensions	Longest 660m	*Lorenz et al,1970*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Lorenz et al,1970*

II. FORM AND STRUCTURE

Subsidence of 150 to 260m along a ring-fault, probable original surface expression greater than 1.5km.

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Diatreme

Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Lorenz et al,1970

First edition - 1976

I. BASIC DATA

Name	**HOLMEN - DAGALI BRECCIA PIPE**	
Alternative names	Dagali-Holmen Breccia Pipe	
Location	Norway	
Geographical position	60.25N 8.27E	*after Oftedahl,1969*
Horizontal dimensions	Diameter 1.5km	*Oftedahl,1960*
Depth		
Altitude		
Rim		
Age	Post Ordovician	*Oftedahl,1960*

II. FORM AND STRUCTURE

Breccia pipe nearly circular in outline.

Oftedahl,1960

III. ORIGIN

Astrobleme

Non astrobleme

Explosion vent
Oftedahl,1960

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**HUNGARIAN PLAIN**	
Alternative names		
Location	Hungary/Roumania	
Geographical position	47.00N 21.00E	*O'Connell,I965*
Horizontal dimensions	440 x 240km	*O'Connell,I965*
Depth		
Altitude		
Rim		
Age	Pliocene	*O'Connell,I965*

II. FORM AND STRUCTURE

A giant meteorite crater rimmed by the Transylvanian Alps.

J.Kaljuvee quoted in Hey,I966

III. ORIGIN

Astrobleme

J.Kaljuvee quoted in Hey,I966

Non astrobleme

Heide quoted in Hey,I966

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**HURDAL** cauldron	
Alternative names		
Location	65 km NNE of Oslo, Norway	
Geographical position	60.25N 10.55E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 5 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

1 km subsidence ? Layering of pyroclastic rocks records repeated subsidence and deposition partly on dry land, partly in shallow caldera lake

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**IIVAARA** complex	
Alternative names		
Location	25 km SW of Kuusamo, NE Finland	
Geographical position	65.50N 28.00E	*after Lehijärvi, 1960*
Horizontal dimensions	3 x 4 km	*Lehijärvi, 1960*
Depth		
Altitude		
Rim		
Age	430 m.y.	*Vartiainen & Wooley,1974*

II.FORM AND STRUCTURE

The alkali rocks of the central zone are surrounded by a 200 - 300 m-broad zone of metasomatically altered rocks .

Lehijärvi, 1960

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Lehijärvi, 1960

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Lehijärvi, 1960

I. BASIC DATA

Name	**ILINTSY**	
Alternative names	Il'inets Il'inetskaya	
Location	45 km SE. of Vinnitsa,USSR	
Geographical position	48.45N 28.00E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 4.5 km Diameter 3.2 km (> 4.0 km)	*Masaytis, 1975* *Val'ter, 1975*
Depth		
Altitude		
Rim		
Age	495 ± 5 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

"...a deeply eroded structure: under a thin cover of Neogene sands and clays, only a lens (up to 200-250 m) of suevites and allogenic breccia has been preserved...."

Masaytis, 1975

The base of the body of impactites rises gently (at angles of 3 to 10 degrees) toward the periphery of the basin.At its edges the angle of rise becomes steeper.

Khryanina. 1978

III.ORIGIN

Astrobleme

Masaytis, 1975
Khryanina, 1978

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
									●			*Masaytis 1975*
		●										*Val'ter, 1975*

I. BASIC DATA

Name	**ILUMETS CRATERS**	
Alternative names	Ilumetsa Craters Larger = Pyrguhaud; Smaller = Süvahaud	
Location	SE. frontier of Estonia	
Geographical position	58.00N 27.03E 58.00N 27.14E 57.58N 25.25E	*Krinov,I966* *O'Connell,I965* *v.Engelhardt,I972*
Horizontal dimensions	Pyrguhaud diameter 80m Süvahaud diameter 50m No.3, 28 x 19m	*Krinov,I966* " " " "
Depth	Pyrguhaud 12m Süvahaud 5.4m No.3,2m	*Krinov,I966* " " " "
Altitude		
Rim	Pyrguhaud max.height 6m,breadth 15m Süvahaud max.height 1.5m,breadth 20m	*Krinov,I966* " "
Age	Over 2,000yrs	*Krinov,I966*

II. FORM AND STRUCTURE

Three turf filled hollows in Devonian and Quaternary rocks.

Krinov,I966

III. ORIGIN

Astrobleme

? Krinov,I966

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
●	●							●			

Krinov,I966

I. BASIC DATA

Namp	**INGOZERO** massif	
Alternative names		
Location	Kola Peninsula, USSR	
Geographical position	67.10N 34.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Non astrobleme
Intrusion
Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al,1974

I. BASIC DATA

Name	**JÄNISJÄRVI**	
Alternative names	Yanis'yarvi	
Location	Karelia, USSR	
Geographical position	61.58N 30.55E	*von Engelhardt, 1972*
Horizontal dimensions	11 x 17 km Approx. diameter 20 km 13 x 17 km	*von Engelhardt, 1972* *Eskola, 1921* *Masaytis, 1975*
Depth	Lake depth 50 m	*von Engelhardt, 1972*
Altitude		
Rim		
Age	Pre-Quaternary 700 m.y.	*Eskola, 1921* *Masaytis, 1975*

II.FORM AND STRUCTURE

Deeply eroded structure consisting of a lake with two islands near its center.

von Englehardt, 1972

The circular basin in Proterozoic schists(13 x 17 km) has been flooded by the waters of Lake Yanis'yarvi. Almost at its center are three islands, which consist of impactites and breccias.

Masaytis, 1975

III.ORIGIN

Astrobleme

von Engelhardt, 1972
Masaytis, 1975

Non astrobleme

Glacial excavation of a region shattered by volcanic explosion.

Eskola, 1921

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●	●										*Eskola, 1921*
									●			*Carstens, 1975*
									●	●		*Masaytis, 1975*

I. BASIC DATA

Name	**JASENICE AMPHITHEATRE**	
Alternative names		
Location	Czechoslovakia	
Geographical position	49.29N 17.57E	*after Žebera, I970*
Horizontal dimensions	Diameter 2km	*Žebera, I970*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"It was deepened in the Těšin Shale at a diameter of 2km. The conspicuous elevation in its centre is made up of enormous blocks of Jurassic limestone."

Žebera, I970

III. ORIGIN

Astrobleme

Comet impact
Žebera, I970

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**JUSI PIPE**	
Alternative names		
Location	Swabian Alb, S.Germany	
Geographical position		
Horizontal dimensions	Diameter approx. 1km at a depth of 130m below the original surface	*Lorenz et al,1970*
Depth	See FORM AND STRUCTURE	
Altitude	See FORM AND STRUCTURE	
Rim	See FORM AND STRUCTURE	
Age	5 to 20.4 x 10^6yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

"Bedded pyroclastic deposits at the exposed top of the pipe indicate a crater bowl about 1000m wide, at a depth of 130m below the original surface....Close to the margins of the pipe,the deposits dip inward quite steeply and are cut by small-scale antithetic faults that indicate late-stage subsidence of the filling. Farther down the pipe, stratification due to fall-back of the ejecta into the vent becomes less distinct and finally disappears."

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Diatreme
Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	●	●	●								

Lorenz et al,1970

I.BASIC DATA

Name	**KAALIJARV CRATERS**	
Alternative names	Sall Craters Saarema Island Craters Oesel(Osel)	
Location	Island of Saarema, Estonia	
Geographical position	58.24N 22.40E 58.24N 22.43E	*Krinov,1966* *Monod,1965*
Horizontal dimensions	Largest 110m diameter No.1 diameter 25m No.2 diameter 35 to 53m No.3 diameter 32 to 33m No.4 diameter 20m No.5 diameter 12 to 15m No.6 diameter 25 to 26m	*Krinov,1966* " " " " " " " " " " " "
Depth	Largest(rim crest to lake floor)22m No.1,4m No.2,3.5m No.3,3.5m No.4,3.5m No.5,0.9m No.6,0.65m	*Krinov,1966* " " " " " " " " " " " "
Altitude		
Rim	Largest, 6 to 7m above surrounding area	*Krinov,1966*
Age	4,000 to 5,000yrs	*Krinov,1966*

II.FORM AND STRUCTURE

"The group consists of seven craters spread over an area of 0.75km^2 situated among ploughed fields".

Krinov,1966

III.ORIGIN

Astrobleme

Krinov,1966

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
●			●					●	●		

Krinov,1966

I. BASIC DATA

Name	**KALUGA**	
Alternative names		
Location	USSR	
Geographical position	54.30N 36.15E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 15 km	*Masaytis, 1975*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	360 ± 10 m.y. 400 to 430 m.y.	*Grieve & Robertson, 1979* *Masaytis, 1975*

II. FORM AND STRUCTURE

..." buried beneath Upper Devonian and Lower Carboniferous strata about 800 m thick. It forms a rounded basin a few hundred meters deep...the allogenic breccia... forms a swell rising 300 m above the floor of the basin and 150 to 200 m above the original surface of the Middle Devonian sediments

Masaytis, 1975

III. ORIGIN

Astrobleme

Masaytis, 1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●						●		

Masaytis, 1975

I. BASIC DATA

Name	**KAMENSK**	
Alternative names		
Location	USSR	
Geographical position	48.20N 40.15E	*Grieve & Robertson , 1979*
Horizontal dimensions	Diameter 25 km	*Grieve & Robertson ,1979*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	65 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

The crater has been buried below a 200-300 m sequence of horizontal Danian-Paleocene marls. It has been filled with a breccia of blocks and fragments...In the zone of the central uplift the thickness of the blocky breccia reaches 500-600 m , and the amplitude of the uplift is about 400 m.

Masaytis, 1975

III.ORIGIN

Astrobleme

Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●								

Masaytis, 1975

I. BASIC DATA

Name	**KAMPEN** cauldron	
Alternative names		
Location	WNW of Oslo, Norway	
Geographical position	60.03N 10.27E	*after Segalstad, 1975*
Horizontal dimensions	10 km ? diameter	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

Subsidence about 1 km. The earliest caldera collapse is indicated by occurence of a thick sequence of coarse to gravelly volcanic sandstone...within the upper part of basalt unit B3. The B3 complex is overlain by an arc-shaped zone of coarse breccias, then felsite porphyry. It is tempting to interpret these rocks as a caldera filling and explosion breccia, overlain by ignimbrites.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Segalstad, 1975
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Segalstad, 1975*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name	**KARLA**	
Alternative names		
Location	RSFRS	
Geographical position	57.45N 48.00E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 18 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	10 m.y. Late Miocene - early Pliocene	*Grieve & Robertson, 1979* *Masaytis et al, 1976*

II.FORM AND STRUCTURE

Middle Carboniferous limestone at the center of the structure form an uplift with an amplitude of as much as 300 m. Pliocene and Quaternary clays and other sediments are localized maily within the circular basin and constitute the filling complex which ranged in thickness up to 100 m.

Masaytis et al, 1976

III.ORIGIN

Astrobleme

Masaytis et al, 1976

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
			●						●	●	

Masaytis et al, 1976

I. BASIC DATA

Name	**KATNOSA** ring complex	
Alternative names		
Location	25 km NW of Oslo, Norway	
Geographical position	60.10N 10.35E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 9 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Basic center to syenitic or granitic outer zone

Oftedahl,1978

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**KHIBINA** massif	
Alternative names	Umptek massif Chibina massif	
Location	15 km N of Kirovsk, Kola Peninsula,USSR	
Geographical position	67.30N 34.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	1327 km^2	*Gerasimovsky et al, 1974*
Depth		
Altitude		
Rim		
Age	290 $\pm$ 10 m.y. 392 to 430 m.y.	*Gerasimovsky et al, 1974* *Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

Polyphase intrusion with central type of structure. It is of isometric shape; the steep contacts have been traced at depth for 7 km by geophysical methods. The contact rim of the Khibina massif is compound of exocontact alkaline metasomatic rocks and of endocontact facies of alkali and nepheline syenite. Seven intrusive phases.

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**KIKUT** ring structure	
Alternative names		
Location	N. of Oslo, Norway	
Geographical position	60.03N 10.32E	*after Segalstad, 1975*
Horizontal dimensions	Diameter approximately 8 km 3 to 4 km diameter	*after Segalstad, 1975* *Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

Granitic center to basic outer zone

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Plutonic
Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Segalstad, 1975*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name	**KJARDLA**	
Alternative names		
Location	Est.SSR	
Geographical position	57.00N 22.42E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 4 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	500 ± 50 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Grieve & Robertson, 1979

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**KÖFELS**	
Alternative names		
Location	Tyrol, Austria	
Geographical position	47.13N 10.58E	*von Engelhardt, 1972*
Horizontal dimensions	Diameter 4 km Diameter 5 km	*von Engelhardt, 1972* *O'Connell, 1965*
Depth		
Altitude		
Rim		
Age	8×10^3 years	*von Engelhardt, 1972*

II. FORM AND STRUCTURE

Deeply eroded semicircular basin in the flanks of a glacial U-shaped valley.

von Engelhardt, 1972

III. ORIGIN

Astrobleme

von Engelhardt, 1972

Non astrobleme

landslide

Erismann et al, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
									●			*von Engelhardt, 1972*
●	●	●					●					*Erismann et al, 1977*

I. BASIC DATA

Name	**KONTOZERO**	
Alternative names	Kontozersk	
Location	Kola Peninsula, USSR	
Geographical position	68.40N 36.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	410 m.y. Paleozoic	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Non astrobleme

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**KOVDOR**	
Alternative names	Kovdorozero Kouterojärvi	
Location	Kola Peninsula, USSR	
Geographical position	67.50N 30.25E	*after Gerasimovsky et al,74*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	370 m.y. Caledonian	*Vartiainen & Wooley, 1974* *Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Complex of ijolite, alkali syenite and carbonatite.

Gittins, 1966

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Borodin & Pavlenko, 1974

I. BASIC DATA

Name	**KOVDOZERO**	
Alternative names	Kovdozersk Koutajärvi	
Location	Kola Peninsula, USSR	
Geographical position	Approx. 67.00N 32.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	37.5 km^2, 8 x 5.5 km	*Gittins, 1966*
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II. FORM AND STRUCTURE

The central part of the intrusion is olivinite, pyroxenite and peridotite; the latter two form incomplete rings, and the outer part consists of ijolite, melteigite and jacupirangite dipping at 70 to 80 degrees. Between them are two bodies of turjaite also in the form of an incomplete ring

Gittins, 1966

III. ORIGIN

Astrobleme

Non astrobleme

Gittins, 1966
Gerasimovsky et al, 1974

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Gittins, 1966

I. BASIC DATA

Name	**KURGA**	
Alternative names	Kurginskiy	
Location	Kola Peninsula, USSR	
Geographical position	68.10N 35.30E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovšky et al, 1974*

II.FORM AND STRUCTURE

Ultramafic alkaline massif

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al,1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**KURSK**	
Alternative names		
Location	USSR	
Geographical position	51.40N 36.00E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 5 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	250 ± 80 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

In its central part there is an uplift of crushed crystalline basement with an amplitude of up to 250 m,....the structure is concealed below a 200m sequence of Jurassic and Cretaceous strata.

Masaytis, 1975

III.ORIGIN

Astrobleme

Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**LAACHER SEE**	
Alternative names	Lachermaar	
Location	Eiffel, West Germany	
Geographical position	50.25N 7.17E	*after Schminke et al,1973*
Horizontal dimensions	2 x 2.5km	*after Schminke et al,1973*
Depth		
Altitude		
Rim	See FORM AND STRUCTURE	
Age	11,000 BP.	*Schminke et al,1973*

II. FORM AND STRUCTURE

"Laacher See....lies in a small oval basin of complex origin. The highest points around its rim are cinder- and lava-cones of alkalic basalts, formed about 40,000 years ago."

Schminke et al,1973

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic

Schminke et al,1973

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Schminke et al,1973

I. BASIC DATA

Name	**LAC BOUCHET**	
Alternative names	Lac du Bouchet	
Location	Massif Central, France	
Geographical position		
Horizontal dimensions	Diameter approximately 1km	*Gallant,1964*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Gallant,1964

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
●											

Gallant,1964

I. BASIC DATA

Name	**LAGO TREMORGIO**	
Alternative names		
Location	Swiss Alps	
Geographical position		
Horizontal dimensions	1.36 to 1.42 km diameter	*Bachtiger,1977*
Depth	250 m Original depth 100 m	*Bachtiger, 1977* *Bachtiger, 1977*
Altitude		
Rim		
Age	20,000 to 50,000 years	*Bachtiger, 1977*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Possibly
Bachtiger, 1977

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**LAIVAJOKI**	
Alternative names		
Location	Finland	
Geographical position	Approx. 65.10N 27.30E	*after Vartiainen & Wooley, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	2020 m.y.	*Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

alkaline complex

Vartiainen & Wooley, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Vartiainen & Wooley, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**LAKE HUMMELN**	
Alternative names		
Location	Småland, south Sweden	
Geographical position	57.24N 16.12E 57.22N 16.15E	*O'Connell,1965* *Svensson,1966*
Horizontal dimensions	Diameter of depressions in southern lake bed = 1km 1.0 x 0.65km 1.3 x 1.0km	*Fredriksson & Wickman,1963* *Svensson,1966* *v.Engelhardt,1972*
Depth	Lake depth 60m,which is 80-90m below general level. Lake 61.5m at deepest point,rim at13m depth.	*Fredriksson & Wickman,1963* *Svensson,1966*
Altitude		
Rim	See Depth	
Age	600 to 700 x 10^6yrs	*Fredriksson & Wickman,1963*

II. FORM AND STRUCTURE

A depression in the bottom of the southern end of the lake.

Fredriksson & Wickman,1963

III. ORIGIN

Astrobleme

Fredriksson & Wickman,1963
Svensson,1966
v.Engelhardt,1972

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	●			●			●				

Svensson,1966

I. BASIC DATA

Name	**LAKE LAATOKKA BASIN**	
Alternative names	Lake Ladoga Lake Ladozhskoye Oz	
Location	Karelia, USSR	
Geographical position	60.13N 31.00E	*after Eskola,I92I*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"...analagous volcanic formations in the basin of Lake Laatokka.Boulders of volcanic amygdaloids and agglomeraters,some of which contain volcanic glass,are found on the islands of Valamo,mainly built up of diabase and quartz-diabase...."

Eskola,I92I

III. ORIGIN

Astrobleme

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**LAKE MIEN**	
Alternative names	Mienstrukturen	
Location	30 km N. of Karlshamn, Sweden	
Geographical position	56.25N 14.52E 56.25N 14.55E	*Stanfors, 1973* *von Engelhardt, 1972*
Horizontal dimensions	5 km diameter (rhombic) Diameter 4 to 5 km, area 20 km^2	*Stanfors, 1973* *Svensson & Wickman,1965*
Depth	W. side of lake 2 to 14 m deep,E. deeper E. side of lake 43 m deep	*Stanfors, 1973* *von Engelhardt, 1972*
Altitude	94.8 m asl.	*Stanfors, 1973*
Rim		
Age	Less than 50 x 10^6 years 92 + 6 x 10^6 years 119 ± 2 m.y.	*Fredriksson & Wickman,1963* *Stanfors, 1973* *Bottomley et al, 1978*

II.FORM AND STRUCTURE

In Precambrian granite-gneiss basement with glacial drift cover. West side of lake demarcated by N20W fault. Drill on Ramso Island showed 3 to 5 m of moraine underlain by 20 to 25 m of "dellenite" lava-like rocks overlying 2 m of tuff-like breccia which lies on a basal granite breccia. Large negative gravity anomaly and positive magnetic anomalies.

Stanfors, 1973

III.ORIGIN

Astrobleme

Fredriksson & Wickman,1963
Svensson & Wickman, 1965
von Engelhardt, 1972
Stanfors, 1973

Non astrobleme

Glacial excavation of a region shattered by a volcanic explosion.
Eskola, 1921

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
									●			*Svensson & Wickman, 1965*
								●	●			*von Engelhardt, 1972*
●	●	●		●	●	●		●	●			*Stanfors, 1973*
		●							●			*Bottomley et al, 1978*

I. BASIC DATA

Name	**LANGESUNDSFJORD** cauldron	
Alternative names		
Location	Centered 5 km NW of Larvik, Norway	
Geographical position	59.05N 10.05E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter approx. 12 km	*after Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

A larvikite which has a semi-circular periphery extending...for about 120 degrees. A ring fault against bed rocks lies outside of it... the circular periphery of the larvikite body is due to a cauldron ring fault that was later followed by larvikite which stoped and consumed nearly all of the subsided block.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

First edition - 1976

I. BASIC DATA

Name **LANGLIA RING-STRUCTURE**

Alternative names

Location N.of Oslo,Norway

Geographical position 60.05N 10.30E *after Segalstad,1975*

Horizontal dimensions

Depth

Altitude

Rim

Age Permian *Segalstad,1975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Non astrobleme

Plutonic
Segalstad,1975

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Segalstad,1975

I. BASIC DATA

Name	**LAPPAJÄRVI** structure	
Alternative names	Lake Lappajarvi	
Location	320 km north of Helsinki, Finland	
Geographical position	63.10N 23.40E 63.09N 23.42E	*Svensson, 1971* *Lehtinen,1976*
Horizontal dimensions	Diameter of impact melt 5 to 6 km Lake diameter 24 x 12 km Diameter 17 x 10 km Diameter 12 to 14 km	*Svensson, 1971* *Lehtinen, 1970* *von Engelhardt, 1972* *Lehtinen, 1976*
Depth	Average depth of lake 5 to 10 m	*von Engelhardt, 1972*
Altitude		
Rim		
Age	Precambrian to Pleistocene Less than 1800 m.y.	*von Engelhardt, 1972* *Lehtinen, 1976*

II.FORM AND STRUCTURE

Topography of the Lake Lappajarvi area is rather flat.....The 80 m contour forms a rough circle around the lake area, excluding the southern and northern corners of the lake... and has a diameter of about 14 km.

Lehtinen, 1976

III.ORIGIN

Astrobleme

Lehtinen, 1970
Svensson, 1971
von Engelhardt, 1972

Non astrobleme

Glacial deepening of a region shattered by volcanic explosion.
Eskola, 1921

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
									●			*Lehtinen, 1970*
	●								●			*Svensson, 1971*
	●	●			●	●			●	●		*Lehtinen, 1976*

I. BASIC DATA

Name	**LA SAUVETAT**	
Alternative names		
Location	Puy de Dôme, France	
Geographical position	44.52N 01.31E	
Horizontal dimensions	Diameter approximately 1.5km	*Gallant,1964*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

? Gallant,1964

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**LESNAYA VARAKA** complex	
Alternative names		
Location	Kola Peninsula, USSR	
Geographical position	67.30N 32.40E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	20 km^2	*Tomkeieff, 1961*
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II. FORM AND STRUCTURE

Outer pyroxenites grade into olivinites toward the center.

Tomkeieff, 1961

III. ORIGIN

Astrobleme

Non astrobleme
Intrusion

Gerasimovsky et al, 1974

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**LOGOISK**	
Alternative names		
Location	Bel.SSR	
Geographical position	54.12N 27.48E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 17 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	100 ± 20 m.y.	*Grieve & Robertson ,1979*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Probably
Grieve & Robertson, 1979

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**LOVOZERO** massif	
Alternative names	Lujavrurt massif	
Location	Central Kola Peninsula, USSR	
Geographical position	68.05N 35.00E	*after Gerasimovsky et al, 1968*
Horizontal dimensions	650 km^2	*Gerasimovsky et al, 1968*
Depth		
Altitude		
Rim		
Age	Post Late Devonian 298 to 303 m.y. 386 to 422 m.y.	*Gerasimovsky et al, 1968* " " " " *Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

The form of the massif in plan is rectangular with rounded corners. It has the form of a laccolith with a broad "base". According to the geophysical data, the alkaline rocks can be traced to a depth of more than 7 km. Two structural units. Its upper part comprises a layered intrusion about 2 km thick and 20 x 30 km in area. The lower stock-like part is displaced to the east relative to the layered body and measures 12 x 16 km. The dip of the contacts of the intrusion are close to vertical *Gerasimovsky et al, 1968*

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Gerasimovsky et al, 1968
Vlasov et al, 1966

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●									*Gerasimovsky et al, 1968*
		●	●									*Vlasov et al, 1966*

I. BASIC DATA

Name	**LUNDBERGKOLLEN** cauldron	
Alternative names		
Location	55 km NNE of Oslo, Norway	
Geographical position	60.26N 10. 50E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 10 km?	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Subsidence 1 km. Area of volcanic rocks and volcaniclastic sediments, that have clearly subsided in relation to Cambro-Silurian sediments a little to the west. This small area is assumed... to represent the remanent of a formerly large caldera block.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**MAVRGUBINSKY** complex	
Alternative names		
Location	Kola Peninsula, USSR	
Geographical position	68.20N 32.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Ultramafic alkaline massif.

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**MEERFELDER MAAR**	
Alternative names		
Location	Eiffel, West Germany	
Geographical position	50.05N 6.45E	*after Lorenz et al,1970*
Horizontal dimensions	Diameter 1.4km 1.48 x 1.2km	*Ollier,1967* *Lorenz et al,1970*
Depth	212m 113 to 212m	*Ollier,1967* *Lorenz et al,1970*
Altitude		
Rim		
Age	10 to 12.3 x 10^3yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

"...northwest end of a volcanic group...the maar which is slightly elongated in a northwest direction...ejecta fans spread to the southeast and west,and the walls of those sides show grooves formed by the abrasive action of the inclined blasts."

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic

Ollier,1967

Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
●												*Ollier,1967*
		●										*Lorenz et al,1970*

I. BASIC DATA

Name	**MENDORF**	
Alternative names		
Location	SW.Germany	
Geographical position	48.46N 11.37E 48.53N 11.36E	*after Rutte,1974* *Classen,1975*
Horizontal dimensions	Diameter 2.6km Diameter 2.5km	*Rutte,1974* *Classen,1975*
Depth	See FORM AND STRUCTURE	
Altitude	410m	*Rutte,1974*
Rim		
Age	14.8×10^6 yrs ?	*Classen,1975*

II. FORM AND STRUCTURE

Infilled crater with central uplift.
Rutte,1974

Very probably several craters
Classen,1975

III. ORIGIN

Astrobleme

Rutte,1971
Classen,1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Rutte,1971*

I. BASIC DATA

Name	**MISARAI**	
Alternative names		
Location	Lith. SSR	
Geographical position	54.00N 23.54E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 5 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	500 $\pm$ 80 m.y.	*Grieve & Robertson, 1979*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Probably

Grieve & Robertson, 1979

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**MISHINA GORA**	
Alternative names	Mishinogorsk	
Location	USSR	
Geographical position	58.40N 28.00E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 2.5. km 4 x 2.5 km	*Grieve & Robertson, 1979* *Shmayenok & Tikhomirov, 1974*
Depth	700 m deep	*Shmayenok & Tikhomirov, 1974*
Altitude		
Rim		
Age	less than 360 m.y. Late Devonian	*Grieve & Robertson, 1979* *Shmayenok & Tikhomirov, 1974*

II.FORM AND STRUCTURE

The structure is rounded in plan and is surrounded by a ring of deformed..sedimentary rocks dipping away...at varying angles. The cup-shaped basin...has been filled with a gigantic allogenic breccia

Masaytis, 1975

III.ORIGIN

Astrobleme

Probably

Masaytis, 1975
Grieve & Robertson, 1979

Non astrobleme

Cryptoexplosion
Shmayenok & Tikhomirov,1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
			●	●								*Shmayenok & Tikhomirov, 1974*
									●	●		*Masaytis, 1975*

I. BASIC DATA

Name	**MOURNE GRANITE**	
Alternative names		
Location	County Down, Northern Ireland	
Geographical position	54.08N 6.00W	*after Charlesworth,1963*
Horizontal dimensions	Diameter 11.6km (7.5 miles)	*Charlesworth,1963*
Depth		
Altitude		
Rim		
Age	Tertiary $75\pm7 \times 10^6$ yrs $58.1\pm1.6 \times 10^6$, $58\pm1.0 \times 10^6$ yrs	*Charlesworth,1963* *Miller & Brown quoted in* *Evans et al,1973*

II. FORM AND STRUCTURE

Five granite intrusions with a cone sheet dipping at 30 degrees.

Charlesworth,1963

III. ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Charlesworth,1963

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●	●	●						

Charlesworth,1963

I. BASIC DATA

Name	**MULL COMPLEX**	
Alternative names		
Location	West Scotland	
Geographical position	56.28N 5.56W	*after Richey et al,I96I*
Horizontal dimensions	NW. caldera 8 x 5.5km SE. caldera 9 x 7km	*Richey et al,I96I* " "
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Tertiary Slightly older than 61 x 10^6 yrs	*Richey et al,I96I* *Evans et al,I973*

II. FORM AND STRUCTURE

Two calderas with ring dykes and cone sheets.In the NW. caldera there has been 150m subsidence on inner ring fault.

Lewis,I968

Subsidence of 950m on a 70 to 80 degree dip fault in the NW. caldera.

Bailey et al,I924

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion and extrusion

Bailey et al,I924
Richey et al,I96I
Lewis,I968

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●								

Richey et al,I96I

I. BASIC DATA

Name	**MYKLE** ring structure	
Alternative names		
Location	20 km north of Skien, Norway	
Geographical position	59.40N 9.45E	*after Segalstad, 1975*
Horizontal dimensions	About 23 x 16 km 18 x 22 km	*after Segalstad, 1975* *Oftedahl, 1978*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

"Along the border of the ring structure there is a depression in the terrain which can be readily seen on aerial photos and topographic maps.Outside this depression the larvikite has an angular surface and is overgrown by spruce trees, while on the inner side the larvikite has a rounded surface expression and supports pine trees... though the extent of the subsidence is difficult to estimate.It may have exceeded 1500 m ... The ring dyke is usually 4 to 8 m wide..."

Segalstad, 1975

III.ORIGIN

Astrobleme

Non astrobleme
Cauldron subsidence

Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●		●		●						*Segalstad, 1975*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name NETOLICE EXPLOSION CRATER

Alternative names

Location Czechoslovakia

Geographical position 49.03N 14.12E *after Žebera, I970*

Horizontal dimensions

Depth

Altitude

Rim

Age 14 to 15 x 10^6 yrs *Žebera, I970*

II. FORM AND STRUCTURE

"A striking depression is there filled with chaotically deposited sediments of very unusual character for the South-Bohemian basins."

Žebera, I970

III. ORIGIN

Astrobleme

Comet impact
Žebera, I970

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**NITTEDAL** cauldron	
Alternative names		
Location	15 km NE of Oslo, Norway	
Geographical position	60.03N 10.38E	*after Oftedahl, 1969*
Horizontal dimensions	15 x 10 km 11 km diameter	*after Oftedahl, 1969* *Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Big caldera formerly assumed to be just a remnant of a smaller caldera, the Alnsjo caldera (q.v.).

Oftedahl, 1969

Subsidence 0.8 km.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1969

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Oftedahl, 1978

I. BASIC DATA

Name	**NORDLIKAMPEN** ring complex	
Alternative names		
Location	60 km NNE of Oslo, Norway	
Geographical position	60.30N 10.58E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 5 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

Granitic center to basic outer zone

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**NORRA KÄRR**	
Alternative names		
Location	1.5 km E of Lake Vattern, Sweden	
Geographical position		
Horizontal dimensions	1.1 x 0.4 km	*von Eckermann, 1968*
Depth		
Altitude		
Rim		
Age	1020 m.y. 1580 ± 62 m.y.	*von Eckermann, 1968* *Kresten et al, 1977*

II.FORM AND STRUCTURE

The alkaline area is ....an intrusion surrounded by a fenite zone of 25 to 100 m width.

von Eckermann et al, 1960

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

von Eckermann et al, 1960

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

von Eckermann et al, 1960

I. BASIC DATA

Name	**OBOLON'**	
Alternative names		
Location	USSR	
Geographical position	49.30N 32.55E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 15 km Diameter about 12 km	*Grieve & Robertson ,1979* *Masaytis, 1975*
Depth	900 m	*Masaytis, 1975*
Altitude		
Rim		
Age	160 m.y. Bajocian	*Grieve & Robertson, 1979* *Val'ter et al, 1978*

II.FORM AND STRUCTURE

The basin formed in rocks of the crystalline basement and the sedimentary cover is filled by allogenic explosion breccia with a thickness of at least 200 to 250 m. 200 to 300 m central uplift of the crystalline basement

Masaytis, 1975

III.ORIGIN

Astrobleme

Masaytis, 1975
Val'ter et al, 1978

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
			●						●			*Masaytis et al, 1976*
									●			*Val'ter et al, 1978*

I. BASIC DATA

Name	**OPPKUVEN BRECCIA PIPE**	
Alternative names	Oppkuven Cauldron	
Location	Norway	
Geographical position		
Horizontal dimensions	Diameter approximately 5km	*Oftedahl,1960*
Depth		
Altitude		
Rim		
Age	Post Ordovician	*Oftedahl,1960*

II. FORM AND STRUCTURE

Breccia pipe with a rounded outline.

Oftedahl,1960

III. ORIGIN

Astrobleme

Non astrobleme

Explosion funnel

Oftedahl,1960

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**ØYANGEN** cauldron	
Alternative names		
Location	Norway	
Geographical position	60.05N 10.25E	*after Oftedahl, 1969*
Horizontal dimensions	Diameter approximately 8 km 10 x 7.5 km	*Oftedahl, 1960* *Oftedahl, 1978*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Oftedahl, 1960*

II.FORM AND STRUCTURE

Eroded subsidence cauldron which dropped 3 to 4 km. "The western quadrant of its ring fault is now taken up by a marginal intrusion or ring dyke, and the eastern half of the cauldron block is removed by stoping of the nordmarkitic magma mass."

Oftedahl, 1960

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Oftedahl, 1960

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Oftedahl, 1978

I. BASIC DATA

Name	**OZERNAYA VERAKA**	
Alternative names	Ozernaya Varaka	
Location	Kola Peninsula, USSR	
Geographical position	Approx. 67.30N 32.30E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	1 km^2	*Tomkeieff, 1961*
Depth		
Altitude		
Rim		
Age	Caledonian 365 to 400 m.y.	*Gerasimovsky et al, 1974* *Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

Exocontact fenitized zone varies in width from 10 m to 60 m. Peripheral urtite-ijolite-melteigite series grades into alkali pyroxenites toward the center.

Tomkeieff, 1961

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Tomkeieff, 1961
Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Gittins, 1966

I. BASIC DATA

Name	**PESOTCHNIY**	
Alternative names		
Location	Kola Peninusla, USSR	
Geographical position	approx. 66.00N 37.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Ultramafic alkaline massif

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Gerasimovsky et al, 1974

I. BASIC DATA

Name	**PFAHLDORF CRATERS**	
Alternative names	Pfahldorf Basin Pfahldorf, Mandelgrund, and Sornhüll	
Location	SW.Germany	
Geographical position	48.54N 11.22E 48.57N 11.22E	*Rutte,I97I* *Classen,I975*
Horizontal dimensions	Greater than 2km diameter 3 craters,diameters 1.5km,1km,1km. Diameter 2.5km	*Rutte,I97I* *Rutte,I974* *Classen,I975*
Depth	30m	*Rutte,I974*
Altitude	450m	*Rutte,I974*
Rim		
Age	14.8×10^6 yrs ?	*Classen,I975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Rutte,I974
Classen,I975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●					●			*Rutte,I97I*

First edition - 1976

I. BASIC DATA

Name	**PÖSING-WETTERFELD DEPRESSION**	
Alternative names	Cham Depression Stamsried-Pemfling-Katzbach Depression	
Location	West Germany	
Geographical position	49.14N 12.37E	*Classen, 1975*
Horizontal dimensions	Diameter about 1km	*Classen, 1975*
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen, 1975*

II. FORM AND STRUCTURE

Depression of many craters.
Classen, 1975

(see also CHAM and STAMSRIED-PEMFLING-KATZBACH depressions)

III. ORIGIN

Astrobleme

Classen, 1975

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**PUCHEZH-KATUNKI**	
Alternative names		
Location	USSR	
Geographical position	57.06N 43.35E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 80 km	*Masaytis, 1975*
Depth	600 m	*Masaytis, 1975*
Altitude		
Rim		
Age	183 ± 3 m.y.	*Masaytis, 1975*

II.FORM AND STRUCTURE

"...form of a sloping funnel in sedimentary deposits resting horizontally on the crystalline basement...It has been filled with an allogenic breccia. In the center of the funnel is an uplift of gneiss and authigenic breccia, about 10 km across. The amplitude of the central uplift is about 2 km.

Masaytis, 1975

III.ORIGIN

Astrobleme
Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●						●		

Masaytis, 1975

I. BASIC DATA

Name	**PULVERMAAR**	
Alternative names		
Location	Eiffel, West Germany	
Geographical position	50.08N 6.50E	*after Lorenz et al,1970*
Horizontal dimensions	0.8 to 0.9km	*Lorenz et al,1970*
Depth	74m 124m	*Ollier,1967* *Lorenz et al,1970*
Altitude		
Rim	See FORM AND STRUCTURE	
Age	Less than 10 to 12.5 x 10^3yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

Almost circular.

Ollier,1967

Funnel shaped with flat-bottomed floor and surrounded by 10 metre thick pyroclastic ejecta.

Lorenz et al,1970

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic

Ollier,1967
Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name RADHOŠŤ AMPHITHEATRE

Alternative names

Location Czechoslovakia

Geographical position 49.35N 18.15E *after Žebera, 1970*

Horizontal dimensions

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

"Semicircular Radhošť amphitheatre on the south-eastern side of the central summit of Mt.Radhošť ....right on the top....in subhorizontal sand-stone beds...."

Žebera, 1970

III. ORIGIN

Astrobleme

Comet impact
Žebera, 1970

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**RAMNES** caldera	
Alternative names		
Location	75 km SSW of Oslo Norway	
Geographical position	59.36N 10.16E	*after Oftedahl, 1969*
Horizontal dimensions	14 x 10 km	*after Oftedahl, 1969*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1969*

II.FORM AND STRUCTURE

The volume of subsidence(about 2 km) of the caldera block in all cases exceeded that of the ignimbrites in the caldera and resulted in high and steep caldera walls which produced breccia sheets between each ignimbrite eruption.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme
Caldera
Oftedahl, 1969

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●	●							*Ramberg, 1976*
		●		●								*Oftedahl 1978*

I. BASIC DATA

Name	**RANDECKER MAAR**	
Alternative names		
Location	S.Germany	
Geographical position	48.58N 11.50E	*Classen,I975*
Horizontal dimensions	Diameter about 1km Diameter about 1km	*Gallant,I964* *Lorenz et al,I970*
Depth	60 to 80m	*Lorenz et al,I970*
Altitude		
Rim		
Age	5 to 20.4 x 10^6yrs	*Lorenz et al,I970*
	14.8 x 10^6yrs ?	*Classen,I975*

II. FORM AND STRUCTURE

"...subsidence continued into Pliocene time.A deep gorge cut through one side of the maar exposes deep levels of the underlying pipe".
Lorenz et al,I970

III. ORIGIN

Astrobleme

? *Gallant,I964*
Classen,I975

Non astrobleme

Volcanic
Lorenz et al,I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
●											

Gallant,I964

First edition - 1976

I. BASIC DATA

Name	**RHUM COMPLEX**	
Alternative names	Rum	
Location	Inner Hebrides, W.Scotland	
Geographical position	57.00N 6.25W	*after Richey et al,I96I*
Horizontal dimensions	Eroded by sea at the edges, present size 11.2 x 8km(7 x 5 miles)	*Wager & Brown,I968*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Tertiary	*Richey et al,I96I*

II. FORM AND STRUCTURE

Intrusive rocks with rhythmic layering,cone sheets and dykes uplifted more than 950m.
Wager & Brown,I968

III. ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Wager & Brown,I968
Dunham,I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		•		•								*Richey et al,I96I*
					•							*McQuillin & Tuson,I963*
		•	•									*Wager & Brown,I968*

I. BASIC DATA

Name	**RIESKESSEL**	
Alternative names	Ries Structure Nordlinger Ries	
Location	S rim of Sudwestdeutsche Gross-Scholle,W.Germany	
Geographical position	48.53N 10.37E	*v.Engelhardt, 1972*
Horizontal dimensions	Diameter 25 km (15 miles) Diameter 22-24 km,with inner zone 8 km diameter Transient cavity about 10 km diameter	*Baldwin, 1963* *Dennis, 1971* *Pohl et al, 1977*
Depth	Max. known crater fill = 300 m of lake deposits Bottom 700 m below present surface Still meteoritic material greater than 1.2 km	*Dennis, 1971* *Bucher, 1963* *Karaszewski, 1974*
Altitude	Plain 420 m asl.	*Dennis, 1971*
Rim	see FORM AND STRUCTURE	
Age	End of Tortonian times 15 to 20 x 10^6 years 14.8 $\pm$ 0.7, 14.0 $\pm$ 0.6 x 10^6 years	*Bucher. 1963* *Baldwin, 1963* *Dennis, 1971*

II.FORM AND STRUCTURE

"...a prominent N-NW facing scarp is interupted by a roughly circular depression...an inner zone with only modest surface relief, followed outward by a concentric zone of flat to hummocky relief... ..The undisturbed crystalline basement of the Ries originally was overlain by a sequence of Mesozoic sedimentary rocks, roughly 600 m thick

Dennis, 1971

III.ORIGIN

Astrobleme

Werner, 1904
Shoemaker & Chao, 1961
Baldwin, 1963
Dennis, 1971
Pohl et al, 1977

Non astrobleme

Volcanic
Bucher, 1963

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
●									●			*Baldwin, 1963*
		●	●	●		●						*Bucher, 1963*
		●		●	●	●		●	●			*Dennis, 1971*
								●				*Karaszewski, 1974*
	●	●	●	●	●	●	●	●	●	●		*Pohl et al, 1977*

I. BASIC DATA

Name	**ROCHECHOUART**	
Alternative names	Chassenon Crater	
Location	Haute Vienne, France	
Geographical position	45.49N 0.50E	*Kraut & French, 1971*
	45.50N 0.56E	*v.Engelhardt, 1972*
Horizontal dimensions	Originally 15 km diameter with 4 km central uplift.	*Kraut & French, 1971*
	Min. 20 km,max. 25 km diameter	*Lambert, 1977*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim	seeFORM AND STRUCTURE	
Age	154 and 173 ± 8 x 10^6 years	*Kraut & French, 1971*
	198 ± 25 and 206 ± 39 x 10^6 years	*Wagner & Storzer, 1975*

II.FORM AND STRUCTURE

"No topographic expression of a circular depression is apparent...The present ground surface lies at approximately the level of the original crater floor."
Kraut & French, 1971

III.ORIGIN

Astrobleme
Kraut & French, 1971
Lambert, 1977

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●						●	●		*Kraut & French, 1971*
		●							●	●		*Lambert, 1977*

I. BASIC DATA

Name	**RÖDERN PIPE**	
Alternative names		
Location	Saar-Nahe Trough, SW. Germany	
Geographical position		
Horizontal dimensions	Longest 750m	*Lorenz et al, 1970*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Lorenz et al, 1970*

II. FORM AND STRUCTURE

Differential subsidence of 500 to 700m along a steeply dipping ring fault. Probable original surface expression greater than 1.5km diameter.

Lorenz et al, 1970

III. ORIGIN

Astrobleme

Non astrobleme

Diatreme
Lorenz et al, 1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●	●	●						·	

Lorenz et al, 1970

First edition - 1976

I. BASIC DATA

Name	**ROSSES RING COMPLEX**	
Alternative names	Rosses Centred Complex Rosses Granite (Complex) Rosses Pluton	
Location	Donegal, Eire	
Geographical position	54.59N 8.27W	*after Pitcher & Berger, I972*
Horizontal dimensions	Roughly circular, 8.5km diameter	*Pitcher & Berger, I972*
Depth	See FORM AND STRUCTURE	
Altitude		
Rim		
Age	$404\pm8 \times 10^6$ yrs 384 ± 8 " " 382 ± 6 " "	*Lambert, I966 and Brown et al, I968 in Pitcher & Berger, I972*

II. FORM AND STRUCTURE

"...there is no direct evidence in the Rosses of the subsidence of a central plug of older rocks, though the situation in the Moorlagh area,....is suggestive of its presence." Four granite stocks dipping at 60 to 70 degrees.

Pitcher & Berger, I972

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion

Pitcher & Berger, I972

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
					●							*Riddihough, I969*
		●	●	●	●							*Pitcher & Berger, I972*

I. BASIC DATA

Name	**ROTMISTROVKA**	
Alternative names		
Location	USSR	
Geographical position	49.00N 32.00E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 2.5 km Diameter 5 km	*Grieve & Robertson, 1979* *Masaytis et al, 1976*
Depth	300 m	*Grieve & Robertson, 1979*
Altitude		
Rim		
Age	70 m.y Late Jurassic or Early Cretaceous	*Grieve & Robertson, 1979* *Masaytis et al, 1976*

II.FORM AND STRUCTURE

The crater has been filled with Cretaceous sediments below which lie breccias.

Masaytis, 1975

III.ORIGIN

Astrobleme

Masaytis, 1975

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
			●						●		

Masaytis et al, 1976

First edition - 1976

I. BASIC DATA

Name	**RÖTZ-WINKLARN DEPRESSION**	
Alternative names	Tiefenbach-Schontahl Depression Rotż-tiefenbach Depression	
Location	West Germany	
Geographical position	49.23N 12.35E	*Classen,I975*
Horizontal dimensions	Diameter about 1km	*Classen,I975*
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen,I975*

II. FORM AND STRUCTURE

Depressions of many craters.

Classen,I975

(see also TIEFENBACH-SCHÖNTHAL DEPRESSION)

III. ORIGIN

Astrobleme

Classen,I975

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Rutte,I974

I. BASIC DATA

Name	**RUNDVATNET**	
Alternative names	Rundevatn Rundevatnet	
Location	N.Norway	
Geographical position	69.27N 19.07E	*Corner,I975*
Horizontal dimensions	100m diameter	*Corner,I975*
Depth	14 to 22m	*Corner,I975*
Altitude	1200m asl.	*Corner,I975*
Rim		
Age	"Young"	*Corner,I975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Corner,I975

Non astrobleme

Avalanche product
Liestøl,I975

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**SÄÄKSJÄRVI**	
Alternative names		
Location	25km E. of Pori, Finland	
Geographical position	61.25N 22.30E	*after Papunen,1969*
Horizontal dimensions	Lake 8 x 4km	*after Papunen,1969*
Depth		
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"......deep erosion level of the crater,which is indicated e.g. by the flat relief of the basin."

Papunen,1973

III. ORIGIN

Astrobleme

Papunen,1969
Carstens,1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●							●			*Papunen,1969*
				●					●			*Papunen,1973*
									●			*Carstens,1975*

I. BASIC DATA

Name	**SAAL**	
Alternative names		
Location	Near Kelheim, West Germany	
Geographical position	48.52N 11.53E	*Classen,1975*
Horizontal dimensions	Original diameter 0.8 to 1.0km	*Rutte,1975*
Depth	13m of sedimentary infilling	*Rutte,1975*
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen,1975*

II. FORM AND STRUCTURE

"Eine Abbauwand des Kalksteinbruchs Saal schneider den randlichen Bereich eines sedimentgefüllten Impactkraters aus dem System der Astrobleme des Rieskometenschweifes auf."

Rutte,1975

III. ORIGIN

Astrobleme

Comet impact
Classen,1975
Rutte,1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
			●						●		

Rutte,1975

I. BASIC DATA

Name — **ST.HIPPOLYTE MAAR**

Alternative names

Location — Auvergne, France

Geographical position

Horizontal dimensions — Diameter approximately 1km — *after Baudry & Camus, I970*

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic
Baudry & Camus, I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Baudry & Camus, I970

I. BASIC DATA

Name — **ST.KILDA - SOAY-BORERAY-LEVENISH - DUN COMPLEX**

Alternative names

Location — Off the Outer Hebrides, Scotland

Geographical position — 57.51N 8.31W — *after Richey et al, I96I*

Horizontal dimensions — Eroded by sea, original diameter 9.6km(6 miles)? *Richey et al,I96I*

Depth

Altitude

Rim

Age — Tertiary
57±3 x 10^6 yrs — *Richey et al,I96I*
Miller & Mohn,I965 quoted in Evans et al,I973

II. FORM AND STRUCTURE

Igneous complex with sheets and dykes centred to a point between the islands.
Richey et al,I96I

III. ORIGIN

Astrobleme

Non astrobleme

Igneous complex
Richey et al,I96I

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Richey et al,I96I

I. BASIC DATA

Name	**ST.MAGNUS BAY DEEP**	
Alternative names		
Location	Shetland Islands, 160km N. of the Scottish mainland	
Geographical position	60.25N 1.34W	*after Flinn,1970*
Horizontal dimensions	Basin 16km diameter,crater 11km diameter	*Sharp,1970*
Depth	Original 900 to 1100m 160m (90 fathoms)	*Sharp,1970* *Flinn,1970*
Altitude		
Rim		
Age	Late Palaeozoic to early Mesozoic Late Tertiary	*Sharp,1970* *Flinn,1970*

II. FORM AND STRUCTURE

"The Shatland islands rise rather sudenly from the sea-floor about 45 fathoms deep, but between the islands in two land-locked bays are two deeps whose bottoms lie at about 80 fathoms."

Flinn,1970

III. ORIGIN

Astrobleme

Flinn,1970
Sharp,1970

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
					●							*McQuillin & Brooks,1967*
						●						*Aeromagnetic map of Great Britain*
●	●	●	●									*Sharp,1970*

I. BASIC DATA

Name	**SALLANLATVI**	
Alternative names	Salanlatvinsky	
Location	Kola Peninsula,USSR	
Geographical position	approx. 66.50N 29.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	3 km diameter	*Gittins, 1966*
Depth		
Altitude		
Rim		
Age	Caledonian	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Central core of carbonatite somewhat elliptical in shape. Surrounding this is a complete ring of ijolite and ijolite-urtite followed by a semi-ring of melteigite. Poorly developed foliation in the alkaline rocks dips inward at 45 to 50 degrees.

Gittins, 1966

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Gittins, 1966

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Gittins 1966

I. BASIC DATA

Name	**SALMOGORSK** massif	
Alternative names	Salmagorsky	
Location	Kola Peninsula, USSR	
Geographical position	approx.67.00N 34.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	480 to 540 m.y. Caledonian	*Vartiainen & Wooley, 1974* *Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Ultramafic alkaline massif.

Gerasimovsky et al 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**SANDE** cauldron	
Alternative names	Sandelakkolith	
Location	40 km SW of Oslo, Norway	
Geographical position	59.40N 10.14E	*after Oftedahl, 1969*
Horizontal dimensions	Diameter 12 km	*Oftedahl, 1953*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Oftedahl, 1953*

II. FORM AND STRUCTURE

"Irregular marginal intrusions along the ring fault, a ring-shaped area of subsided lavas, the central part of which is now occupied by a younger central intrusion." Subsidence 500 to 800 m.

Oftedahl, 1953

III. ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Oftedahl, 1953
Segalstad, 1975

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●	●								*Oftedahl, 1953*
				●		●						*Segalstad, 1975*
		●	●	●	●							*Ramberg, 1976*
		●		●								*Oftedahl, 1978*

I. BASIC DATA

Name	**SAUSTAHL**	
Alternative names		
Location	SW.Germany	
Geographical position	48.56N 11.48E 48.58N 11.50E	*Rutte,I97I* *Classen,I975*
Horizontal dimensions	1.4 to 1.8km diameter 2km diameter	*after Rutte,I97I* *Classen,I975*
Depth	Central 20m; near rim 45m 8m	*Rutte,I974* *Classen,I975*
Altitude	520m	*Rutte,I974*
Rim	8m	*Rutte,I974*
Age	14.8×10^6 yrs ?	*Classen,I975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Rutte,I97I
Classen,I975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	•		•				•	•				*Rutte,I971*
									•			*Rutte,I974*

I. BASIC DATA

Name	**SCHAFFERGRUBE**	
Alternative names		
Location	West Germany	
Geographical position	48.48N 11.50E	*Classen, 1975*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen, 1975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme
Classen, 1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**SCHAFGRABEN**	
Alternative names	Sausthal ?	
Location	West Germany	
Geographical position	48.58N 11.50E	*Classen, 1975*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	14.8 x 10^6 yrs ?	*Classen, 1975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Classen, 1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**SEBLJAVRSK** massif	
Alternative names	Sebl'yavr Sebl-yarvi	
Location	Kola Peninsula USSR	
Geographical position	Approx. 68.30N 32.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	383 m.y Caledonian	*Vartiainen & Wooley, 1974* *Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Ultramafic alkaline massif

Gerasimovsky et al, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**SENÈZE MAAR**	
Alternative names		
Location	Massif Central, France	
Geographical position		
Horizontal dimensions	Approximately 1km diameter	*Lorenz,1973*
Depth	Debris fill to plus 175m	*Lorenz,1973*
Altitude		
Rim		
Age	Villefranchian	*Lorenz,1973*

II. FORM AND STRUCTURE

"A ring fault can be mapped nearly all round the crater floor, separating the gneiss of the wall from the bedded pyroclastic debris of the crater floor."

Lorenz,1973

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic

Lorenz,1973

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●									

Lorenz,1973

I. BASIC DATA

Name	**SILJAN RING**	
Alternative names		
Location	270 km NW of Stockholm, Sweden	
Geographical position	61.05N 15.00E 61.02N 14.52E	*v.Engelhardt, 1972* *Bottomley et al, 1978*
Horizontal dimensions	Overall diameter about 35 km Width 5 to 10 km; outer radius 20 km Diameter 45 km	*Fredriksson & Wickman, 1963* *Stam, 1967* *Rutten, 1966*
Depth		
Altitude		
Rim	see FORM AND STRUCTURE	
Age	Less than 400 x 10^6 years 361.9 $\pm$ 1.1 m.y.	*Fredriksson & Wickman, 1963* *Bottomley et al, 1978*

II. FORM AND STRUCTURE

A group of Precambrian granite hills(outcrops) surrounded by an almost uniform ring of Cambrian/Silurian hills. Parts of the ring are covered by lakes and others by deep overburden.
Fredriksson & Wickman, 1963
32 km central uplift of shocked Dala granite.
Bottomley et al, 1978

III. ORIGIN

Astrobleme

Fredriksson & Wickman. 1963
Bottomley et al, 1978

Non astrobleme

Volcanic
Rutten, 1966
Tectonic
Stam, 1967

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●					●				*Stam, 1967*
		●	●									*Rutten, 1966*
		●							●	●		*Bottomley et al, 1978*

I. BASIC DATA

Name	**SKREHELLE** cauldron	
Alternative names		
Location	N of Skien, Norway	
Geographical position	59.35N 9.43E	*after Segalstad, 1975*
Horizontal dimensions	Diameter approx. 7 km	*Segalstad, 1975*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II. FORM AND STRUCTURE

"The vertical subsidence of the cauldron may have been 1,500 m, corresponding to the apparent thickness of the basalt...The ring dyke is sometimes up to 500 m thick...."

Segalstad, 1975

Traces of a ring fault covering nearly 90 degrees of the periphery...the cauldron block almost completely digested by the later stoping nordmarkite.

Oftedahl, 1978

III. ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence

Segalstad, 1975
Oftedahl, 1978

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●		●		●						*Segalstad, 1975*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name	**SKYE COMPLEX**	
Alternative names		
Location	Inner Hebrides, Scotland	
Geographical position	57.15N 6.05W	*after Wager & Brown, I968*
Horizontal dimensions	Diameter about 8km (5 miles)	*Wager & Brown, I968*
Depth	See FORM AND STRUCTURE	
Altitude	See FORM AND STRUCTURE	
Rim	See FORM AND STRUCTURE	
Age	$52\pm3, 58\pm6, 51\pm4, 54\pm2, 52\pm5 \times 10^6$ yrs	*Various authors in Evans et al, I973*

II. FORM AND STRUCTURE

Three intrusion centres, cones, sheets, and dykes. "The ultrabasic magma...formed a number of laccolitic masses, the largest...at least 2½ miles in diameter and 1,500 feet in thickness ....The great(gabbro)laccolite had a diameter of not less than 10 miles and a thickness of over 3,000 feet.....The granite, like the gabbro, assumed the laccolitic habit in the west and the boss form in the east."

Harker, I904

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion

Harker, I904
Wager & Brown, I968

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●	●									*Harker, I904*
●		●										*Wager & Brown, I968*

I. BASIC DATA

Name SLIEVE GULLION COMPLEX

Alternative names

Location County Armagh, Northern Ireland

Geographical position 54.08N 6.28W *after Charlesworth, 1963*

Horizontal dimensions Diameter 11.2km(7 miles) *Charlesworth, 1963*

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

Two acid ring dykes with basalt and trachyte lavas, vent agglomerates, and crush breccias enclosing granophyre and dolerite.

Charlesworth, 1963

III. ORIGIN

Astrobleme

Non astrobleme

Igneous intrusion

Charlesworth, 1963

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●	●	●									*Bailey & McCallien, 1956*
		●	●	●	●							*Charlesworth, 1963*

First edition - 1976

I. BASIC DATA

Name SLOTTET RING-STRUCTURE

Alternative names

Location N. of Oslo, Norway

Geographical position 60.03N 10.29E *after Segalstad, 1975*

Horizontal dimensions

Depth

Altitude

Rim

Age Permian *Segalstad, 1975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Non astrobleme

Plutonic

Segalstad, 1975

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Segalstad, 1975

First edition - 1976

I. BASIC DATA

Name	**SNOWDON SYNCLINE**	
Alternative names		
Location	North Wales	
Geographical position	52.55N 4.05W	*after Rast,I969*
Horizontal dimensions	Inner caldera 12 x 3.5km;syncline 15 x 7km	*after Rast,I969*
Depth		
Altitude		
Rim		
Age	Initial dome in early Caradocian	*Rast,I969*

II. FORM AND STRUCTURE

"....an anticlinal dome structure preceeding the main episode of volcanicity.The fault system separating the dome and the Snowdon Syncline is thus a volcanotectonic structure representing the rim of a caldera which was soon filled by volcanic ejectamenta,ignimbrites and lavas."

Rast,I969

III. ORIGIN

Astrobleme

Non astrobleme

Volcanotectonic

Rast,I969

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●		●							

Rast,I969

I. BASIC DATA

Name	**SOKLI**	
Alternative names		
Location	North Finland	
Geographical position	67.40N 28.40E	*after Vartiainen & Wooley, 1974*
Horizontal dimensions	20 km^2, about 5 x 4 km	*Vartiainen & Wooley, 1974*
Depth		
Altitude		
Rim		
Age	334 to 378 m.y. 360 m.y.	*Vartiainen & Wooley, 1974* " " "

II.FORM AND STRUCTURE

Around the Sokli intrusion there is a broad metasomatic aureole of fenitization which extends up to 2.5 km from the carbonatite contact.
Vartiainen & Wooley, 1974

A plug of roughly circular cross-section occupying a topographic depression approximately 20 to 30 m deep. Outcrops are scarce and poor. Carbonatite ring dykes and a few tangential dykes have been recorded.
Paarma, 1970

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Vartiainen & Wooley, 1974
Paarma, 1970

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●										*Vartiainen & Wooley, 1974*
		●				●						*Paarma, 1970*

I. BASIC DATA

Name	**SØRØY**	
Alternative names		
Location	Island to north of Norway	
Geographical position	70.30N 23.43E	*Sturt et al, 1967*
Horizontal dimensions		
Depth		
Altitude		
Rim		
Age	384 to 420 m.y.	*Sturt et al, 1967*

II.FORM AND STRUCTURE

The alkaline rocks have been afftected by late phases of deformation and in places are sheared and folded.

Sturt et al, 1967

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Sturt et al, 1967

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**SOULANGES DOLINE**	
Alternative names	Doline of Soulanges	
Location	Grand Causses, France	
Geographical position		
Horizontal dimensions	Diameter 1km	*Small,1972*
Depth	In excess of 60m (200 feet)	*Small,1972*
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

Hollow in limestone.

Small,1972

III. ORIGIN

Astrobleme

Non astrobleme

Solution of limestone

Small,1972

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●										*Small,1972*

I. BASIC DATA

Name	**SOUSTOVA** massif	
Alternative names	Soustovsk Massif	
Location	Kola Peninsula, USSR	
Geographical position	approx. 67.00N 34.00E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	32 km^2	*Gerasimovsky et al, 1974*
Depth		
Altitude		
Rim		
Age	Hercynian	*Gerasimovsky et al, 1974*

II.FORM AND STRUCTURE

Nepheline syenite massif.

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion
Gerasimovsky et al, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**STAMSRIED-PEMFLING-KATZBACH DEPRESSION**	
Alternative names	Cham Depression Posing Weterfeld Depression	
Location	West Germany	
Geographical position	49.14N 12.37E	*Classen, 1975*
Horizontal dimensions	Diameter about 1km	*Classen, 1975*
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen, 1975*

II. FORM AND STRUCTURE

Depression of many craters.
Classen, 1975

III. ORIGIN

Astrobleme

Classen, 1975

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**STEINHEIM BASIN**	
Alternative names	Steinheimer Becken	
Location	65km WSW. of Stuttgart,Germany	
Geographical position	48.02N 10.04E	*O'Connell,I965*
Horizontal dimensions	Diameter 2.4km(1½ miles) Diameter 2.8km(1.8 miles) Diameter 3.5km	*Baldwin,I963* *Bucher,I963* *Classen,I975*
Depth	Greater than 100m?	*Bucher,I963*
Altitude	Central rise 150m Central rise 50 to 55m	*Bucher,I963* *v.Engelhardt,I972*
Rim		
Age	15 to 20 x 10^6yrs Sarmatian?	*Baldwin,I963* *Bucher,I963*

II. FORM AND STRUCTURE

Circular depression with central hill of brecciated rocks.

v.Engelhardt,I972

III. ORIGIN

Astrobleme

Baldwin,I963
v.Engelhardt,I972

Non astrobleme

Volcanic

Bucher,I963

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
●									●	●		*Baldwin,I963*
				●		●				●		*Bucher,I963*

I. BASIC DATA

Name	**STENOVICE** complex	
Alternative names		
Location	Czechoslovakia	
Geographical position		
Horizontal dimensions	Diameter 6 km	*Bartosk et al, 1969*
Depth		
Altitude		
Rim		
Age	340 $\pm$ 12 m.y.	*Bartosek et al, 1969*

II.FORM AND STRUCTURE

Stock of hornblende-biotite granodiorite becoming more basic toward the center.

Bartosek et al, 1969

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Bartosek et al, 1969

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**STOPFENHEIM KUPPEL**	
Alternative names		
Location	South Germany	
Geographical position	49.04N 10.53E	*after Storzer et al,I97I*
Horizontal dimensions	Diameter 8km	*Storzer et al,I97I*
Depth		
Altitude		
Rim		
Age	Post Jurassic	*Storzer et al,I971*

II. FORM AND STRUCTURE

"Uplifted area within Mesozoic sediments,radially faulted with the strata dipping gently outward from the centre."

Storzer et al,I97I

III. ORIGIN

Astrobleme

Storzer et al,I97I

Non astrobleme

Classen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
		●						●			

Storzer et al,I97I

I. BASIC DATA

Name STRYKEN cauldron

Alternative names

Location N. of Oslo, Norway

Geographical position 60.05N 10.32E *after Segalstad, 1975*

Horizontal dimensions Diameter approx. 8 km *after Segalstad, 1975*

Depth

Altitude

Rim

Age Permian *Segalstad, 1975*

II.FORM AND STRUCTURE

"A ring dyke of felsite porphyric composition, sometimes developed as an ignimbrite-like rock.

Segalstad, 1975

Western ring dyke encompasses an arc of 180 degrees and possible ignimbrite on the east.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme

Plutonic
Segalstad, 1975
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Segalstad, 1975*
		●										*Oftedahl, 1978*

I. BASIC DATA

Name	**SVARTEN** cauldron	
Alternative names	Langlia-Storflaaten area	
Location	NW. of Oslo, Norway	
Geographical position	60.04N 10.30E	*after Segalstad, 1975*
Horizontal dimensions	Diameter 11 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

"Most of the caldera block has disappeared in the pluton to the north, leaving only a southern segment. From this relationship Saether infers 1,500 m subsidence."

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non astrobleme
Cauldron subsidence

Segalstad, 1975
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
				●								*Segalstad, 1975*
		●										*Oftedahl, 1978*

First edition - 1976

I. BASIC DATA

Name	**TAZENAT MAAR**	
Alternative names	Gour de Tazenat	
Location	Auvergne, France	
Geographical position		
Horizontal dimensions	Diameter 1.5km	*Lorenz et al,I970*
Depth	67m	*Lorenz et al,I970*
Altitude		
Rim		
Age		

II. FORM AND STRUCTURE

"Volcanic debris forms only a small fraction of the crescent-shaped rim of ejecta around the northern side of the crater."

Lorenz et al,I970

III. ORIGIN

Astrobleme

Non astrobleme

Lorenz et al,I970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

First edition - 1976

I. BASIC DATA

Name	**TIEFENBACH-SCHÖNTHAL DEPRESSION**	
Alternative names	Rotz-Tiefenbach Depression Rotz-Winklarn Depression	
Location	West Germany	
Geographical position	49.23N 12.35E	*Classen, 1975*
Horizontal dimensions	diameter about 1km	*Classen, 1975*
Depth		
Altitude		
Rim		
Age	14.8×10^6 yrs ?	*Classen, 1975*

II. FORM AND STRUCTURE

Depression of many craters

Classen, 1975

see also RÖTZ-WINKLARN DEPRESSION

III. ORIGIN

Astrobleme

Classen, 1975

Non astrobleme

Classen, 1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name TŘEBOŇ

Alternative names

Location Czechoslovakia

Geographical position 49.01N 14.50E *after Rutte,1974*

Horizontal dimensions

Depth

Altitude

Rim

Age

II. FORM AND STRUCTURE

"Kraterlandschaft with shocked minerals"

Rutte,1974

III. ORIGIN

Astrobleme

Rutte,1974

Non astrobleme

Clässen,1977

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
									●		

Rutte,1974

I. BASIC DATA

Name	**TRYVASSHØGDA** ring complex	
Alternative names		
Location	About 8 km N. of Oslo, Norway	
Geographical position	60.05N 10.40E	*after Oftedahl, 1978*
Horizontal dimensions	Diameter 7 km	*Oftedahl, 1978*
Depth		
Altitude		
Rim		
Age	Permian	*Oftedahl, 1978*

II.FORM AND STRUCTURE

...between the Nittedal and Baerum cauldrons. A small area of subsided rhomb porphyries support the conclusion that a small cauldron may have existed here before the Baerum cauldron developed.

Oftedahl, 1978

III.ORIGIN

Astrobleme

Non aştrobleme

Intrusion
Oftedahl, 1978

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
				●							

Oftedahl, 1978

I. BASIC DATA

Name	**TURYI**	
Alternative names	Turja, Turyii, Turii Central'nyy massif	
Location	Kola Peninsula, USSR	
Geographical position	Approx. 66.00N 37.30E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	1 km^2 core	*Bulakh & Iskoz-Dalinina, 1978*
Depth		
Altitude		
Rim		
Age	294 to 373 m.y.	*Polankov & Gerling, 1961*

II. FORM AND STRUCTURE

Dykes penetrating sandstones and quartzites.
Three intrusive phases.
Tomkeieff, 1961

In the core, the carbonatites constitute a vertical stock lying among alkali rocks and melilite-bearing ones.
Bulakh et al, 1972

III. ORIGIN

Astrobleme

Non astrobleme

Intrusion
Bulakh et al, 1972
Gerasimovsky et al, 1974

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●										*Bulakh et al, 1972*
		●	●									*Bulakh & Iskoz-Dalinina, 1978*

I. BASIC DATA

Name	**TVÄREN BAY**	
Alternative names		
Location	Near Studsvik, Sweden	
Geographical position	58.46N 17.25E	*Fredriksson & Wickman, 1963*
Horizontal dimensions	Approximate diameter 2km	*Fredriksson & Wickman, 1963*
Depth	45 to 50m below general bay floor level	*Fredriksson & Wickman, 1963*
Altitude		
Rim		
Age	450×10^6 yrs	*Fredriksson & Wickman, 1963*

II. FORM AND STRUCTURE

A round depression in the bed of the bay.

Fredriksson & Wickman, 1963

III. ORIGIN

Astrobleme

Fredriksson & Wickman, 1963

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**VAASA** structure	
Alternative names	Söderfjärden structure	
Location	8 km S. of Vaasa, western Finland	
Geographical position	63.00N 21.40E	*Talvitie et al, 1975*
Horizontal dimensions	5 to 6 km diameter 5.5 km diameter	*Talvitie et al, 1975* *Lauren et al, 1978*
Depth	At least 200 m Minimum 400 to 500 m	*Talvitie et al, 1975* *Lauren et al, 1978*
Altitude	see FORM AND STRUCTURE	
Rim	see FORM AND STRUCTURE	
Age	Svecokarelidic About 600 m.y.	*Talvitie et al, 1975* *Lauren et al, 1978*

II.FORM AND STRUCTURE

"The circular structure consists of a hilly rim and a flat central basin. On the rim, the Svecokarelidic granitic rocks are exposed on the hilltops, whereas on the flanks these rocks are covered by till and unequal outwash."

Talvitie et al, 1975

Circular plain barely rising above sea-level surrounded by hills rising 20 to 40 m above sea-level. No rock outcrops within basin. Undulating bottom topography.

Lauren et al, 1978

III.ORIGIN

Astrobleme

Possibly

Lauren et al, 1978

Non astrobleme

Subsidence ?

Talvitie et al, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
●	●	●	●	●	●		●					*Talvitie et al, 1975*
●					●			●	●			*Lauren et al, 1978*

I. BASIC DATA

Name	**VEALØS** cauldron	
Alternative names		
Location	East of Skien, Norway	
Geographical position	59.30N 9.50E	*after Segalstad, 1975*
Horizontal dimensions	Approx. 15 km diameter 10 to 20 km diameter	*Segalstad, 1975* *Oftedahl, 1978*
Depth	see FORM AND STRUCTURE	
Altitude		
Rim		
Age	Permian	*Segalstad, 1975*

II.FORM AND STRUCTURE

" The ring fault has displaced the B_1 basalt in the southwestern part, and a nordmarkite-syenite ring-dyke of variable thickness has intruded along the ring fault...The vertical subsidence is difficult to estimate from the present data, but may have been of the magnitude of 1,500 m.."

Segalstad, 1975

III.ORIGIN

Astrobleme

Non astrobleme

Cauldron subsidence
Segalstad, 1975

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●		●		●						*Segalstad, 1975*
				●								*Oftedahl, 1978*

I. BASIC DATA

Name	**VEPRIAJ**	
Alternative names		
Location	Lith. SSR	
Geographical position	55.06N 24.36E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 8 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	160 ± 30 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme

Probably

Grieve & Robertson, 1979

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

I. BASIC DATA

Name	**VUORIJARVI** massif	
Alternative names	Vuoriyarvi Kuolo-yarvi	
Location	Kola Peninsula, USSR	
Geographical position	approx. 67.00N 29.50E	*after Gerasimovsky et al, 1974*
Horizontal dimensions	19.5 km^2 6 x 3 km	*Gittins, 1966* *Kapustin, 1974*
Depth		
Altitude		
Rim		
Age	Caledonian 380 to 402 m.y.	*Gerasimovsky et al, 1974* *Vartiainen & Wooley, 1974*

II.FORM AND STRUCTURE

Oval. Four intrusive phases. Elliptical ring complex elongated east and west. The central part of the complex is a mass of pyroxenite with inward dip of 65 to 80 degrees. Surrounding the pyroxenite is a complete ring of ijolite, melteigite, jacupirangite and malignite, 100 to 140 m thick.

Gittins, 1966

The oldest rocks form the main part of the massif. The internal structure of the massif is extraordinarily complicated.

Kapustin, 1974

III.ORIGIN

Astrobleme

Non astrobleme

Intrusion

Gittins, 1966
Kapustin, 1974

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
		●										*Gittins, 1966*
		●		●								*Kapustin, 1974*

First edition - 1976

I. BASIC DATA

Name	**WEINFELDER MAAR**	
Alternative names		
Location	Eiffel, West Germany	
Geographical position		
Horizontal dimensions	0.575 x 0.065m	*Lorenz et al,1970*
Depth	137m 67 to 87m	*Ollier,1967* *Lorenz et al,1970*
Altitude		
Rim		
Age	10.5 to 11 x 10^3yrs	*Lorenz et al,1970*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Non astrobleme

Volcanic
Ollier,1967
Lorenz et al,1970

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12
	●	●	●				●				

Lorenz et al,1970

I. BASIC DATA

Name	**WIPFELSFURT**	
Alternative names		
Location	Bayern, SW.Germany	
Geographical position	48.58N 11.50E	*Classen,1975*
Horizontal dimensions	Diameter 1km	*Rutte,1974*
Depth	120m (secondary)	*Rutte,1974*
Altitude	420m	*Rutte,1974*
Rim		
Age	14.8×10^6 yrs ?	*Classen,1975*

II. FORM AND STRUCTURE

III. ORIGIN

Astrobleme

Rutte,1971
Classen,1975

Non astrobleme

IV. SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12	
	●						●					*Rutte,1971*
									●			*Rutte,1974*

I. BASIC DATA

Name	**ZELENY GAI**	
Alternative names		
Location	Ukr. SSR	
Geographical position	47.25N 35.23E	*Grieve & Robertson, 1979*
Horizontal dimensions	Diameter 1.4 km	*Grieve & Robertson, 1979*
Depth		
Altitude		
Rim		
Age	120 ± 20 m.y.	*Grieve & Robertson, 1979*

II.FORM AND STRUCTURE

III.ORIGIN

Astrobleme
Probably
Grieve & Robertson, 1979

Non astrobleme

IV.SPECIFIC STUDIES

1	2	3	4	5	6	7	8	9	10	11	12

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SECTION II:

Abstracts of Results of the Planetary Geology Intern Program.

THE PLANETARY GEOLOGY INTERN PROGRAM

Abstracts Covering Research Projects for Summer 1980

The Planetary Geology Intern Program was established four years ago as an offshot of the highly successful Viking Intern Program. It has provided undergraduates with an opportunity to consider planetary work by actually becoming involved in on-going research with NASA-sponsored Principal Investigators. Following is a summary of projects in which PGIP participants were actively involved during the summer of 1980. Interns whose abstracts have been included in this publication are:

Richard P. Binzel, senior at Macalester College, MN Hosted by Dr. Eugene Shoemaker/Eleanor Helin at Cal Tech, Pasadena, CA

Stephen H. Brown, senior at Univ. of Massachusetts, Amherst Hosted by Dr. James Head, Brown Univ., Providence, RI

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* * *

PLANET CROSSING ASTEROID SURVEY

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BACKGROUND

This survey was undertaken in 1973 by Eugene M. Shoemaker and Eleanor F. Helin of the California Institute of Technology in order to determine the population of asteroids whose orbits cross Mars, Earth, and Venus. Results from this survey combined with results of previous studies will give improved estimates of the cratering rates on these planets.

Time exposures of selected areas of the sky are made monthly primarily with the 18 inch and occasionally the 48 inch Schmidt telescope at Mount Palomar Observatory in order to search for these planet crossing asteroids as their orbital motion causes them to display short trails. A typical 48 inch Schmidt photographic plate may reveal several hundred trails, many being among the over 2000 numbered asteroids, but the majority being previously undiscovered objects whose orbits are within the main asteroid belt. Planet crossing asteroids are identifiable on a plate by their relatively fast apparent motion, but such objects are a rare find with a discovery rate of only one or two per year. Besides making positional measurements and orbital determinations for the objects of primary interest, the newly discovered planet crossing asteroids, an effort is made to also measure positions and determine orbits for the numerous newly discovered main belt objects.

RESEARCH

In 1978, 150 new main belt asteroids were discovered on plates taken by Helin and Shoemaker over a two month interval

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using the 48 inch Schmidt. These objects were measured and preliminary orbits for them were determined. Under the direction of Schelte J. Bus, I used these preliminary orbits and the record plates taken with the 48 inch Schmidt to determine whether some of these objects may have shown up on plates taken prior to their discovery. This search was centered around their 1977 opposition and uncovered potential plates for 56 of the objects. Of these, 38 objects were on plates taken by Charles Kowal of Caltech as part of his Solar System Survey. Since these plates were readily accessible, I concentrated my examination on them and was able to search for 23 of the objects. Each of the plates examined showed numerous asteroid trails, but images having a suitable match to the positions and orbital motions predicted by the preliminary orbits were found for only 12 of the objects, roughly 50 percent. The positions of these objects were then measured to better than one arcsecond precision and have been reported to Brian Marsden of the Smithsonian Astrophysical Observatory and will be published in the Minor Planet Circulars. These additional positions will allow great refinements to be made in the preliminary orbits of these objects which will lead to their permanent number and name assignments.

I was also able to participate in two observing sessions at Mount Palomar using the 18 inch Schmidt telescope on a total of five nights. Approximately 20 exposures were taken each night with the work consisting of telescope guiding and developing the films. Each film was scanned with a binocular microscope to detect fast moving asteroids, but no such objects were found during my stay.

ACKNOWLEDGMENTS

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THE GEOLOGY OF THE ELYSIUM REGION OF MARS

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August 23, 1980

The Elysium region of Mars, located in the vicinity of 215°W, 25°N, is one of the two major volcanic provinces on the planet. The geology of the other younger volcanic region, Tharsis, has been extensively studied by such workers as Schaber et al (1). However, the overall geology of the Elysium region has been neglected; with previous studies in the region having concentrated on specific volcanic constructs (2,3) or the fossae and associated channels (4,5,6). The purpose of this study is therefore to explore in detail the geology of the Elysium region with special emphasis being placed on determining the manner in which the surface features were formed.

The first part of this project involved the detailed mapping of the region. Medium resolution Viking Orbiter pictures (frames 541A03-541A06, 732A11-732A16, 844A11-844A22, 844A39-844A46, and 846A17-846A22) were used to delineate map units on an orthographically corrected photomosaic (frames 844A09-844A46). The boundaries in the unit map were chosen based upon both differences in distinctive composition and mode of emplacement as well as differences in morphology in those cases where post emplacement processes have significantly altered the terrain.

In addition, morphometric measurements of the Elysium fossae and associated channels were obtained. From sinuous channels in the region, measurements were taken of channel bankfull widths and associated wavelengths. Moreover, widths and associated planimetric areas were taken from streamlined forms, as defined by Baker (7), located within an anastomizing Elysium channel. This channel was located on a high resolution photomosaic composed of Viking Orbiter pictures (frames 651A01-651A24). The planimetric areas were measured using an area calculating computer program in conjunction with a digitizing board. These morphometric measurements were taken in an attempt to determine the origin of the Elysium fossae and associated channels.

Lastly, a chronology was determined for the events acting in the Elysium region which led to the formation of the surficial units. The major criterion for separating the units based on their relative ages was the superposition of adjacent units at a common boundary. Moreover, an erosive unit which cut into another unit was determined to be younger than that unit.

The major result of this investigation is that the Elysium region has been divided into sixteen morphologically distinct units. Ten of these units were formed by constructive processes involving volcanic activity; whereas, the other six units were formed by destructive processes involving one or more erosive agent(s).

Also, the Elysium fossae and associated channels can be separated into two groups when wavelength versus width measurements are plotted on log versus log paper. One group probably had a fluvial origin based upon similarities between the channels in the group and the catastrophically flooded scablands of Washington (7). The other group probably formed by erosion from turbulent lava flows based upon similarities between the channels in this group and sinuous rilles on the moon.

The measurements of length versus planimetric area of streamlined forms were obtained from a channel which belonged to the fluvial origin group based upon the above sinuosity measurements. A plot of the points on log versus log paper coincided very well with data which Baker and Kochel (8) obtained from the scablands of Washington on the Earth and the Maja and Kasei Vallis regions on Mars. This strongly supports the finding that this channel (and those morphologically similar) was formed by catastrophic flooding.

Finally, the constructive volcanic units of the Elysium region were generally followed by the erosive destructional units. This generality is complicated by the existence of more than one type of erosive agent. It appears that in many cases, one of the erosive agents, water, reached the surface at the same location as lava. In some cases the lava had been acting as a destructive agent characterized by erosive turbulent flows; in other cases the lava had been acting as a constructive agent characterized by large scale surface flows. Invariably, the water came after the lava.

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THE HEIGHTS OF DUNES ON MARS

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On Mars, there are many areas which have what appear to be dunes. In my area of study, the north polar region of Mars, there are vast fields of transverse and barchan dunes. These fields cover an area on the order of one million square kilometers, which is as large as the great sand seas of North Africa.

Presence of dunes on Mars and information from the Viking landers have created some interesting questions. The Viking landers have shown an apparent lack of any sand size particles on the surface near the lander. This may be a condition local to the landing sites, but if this lack of sand material were planetwide, it raises the question of what the dunes are made. The absence of sand material may be due to the so called kamikaze effect (Sagan et al., 1977), which states that under present Martian conditions saltating grains would tend to destroy themselves.

Another paradox discovered at the landing sites was that the wind velocities were below what is needed for grains to start saltating and be moved into dune forms (Sagan et al., 1977). Again, this may be a local condition, but if this is true over the whole planet, then the dunes may be presently inactive.

If these conditions are true for the whole planet, then it seems unlikely that dunes could be formed or are active under present circumstances. It may be that the dunes that are present were formed in the past when atmospheric conditions were more favorable.

In order to understand under what conditions the dunes were formed and under what conditions they are presently being subjected, it was necessary to establish the morphological characteristics of the dunes, such as height, width, and length. Using a photo illumination method devised by Arthur (1980), determinations of the heights of fourteen individual barchan dunes taken from Viking frame 524B21, were made.

Widths of dunes were then measured. This was done so that directly measured width data could be compared with widths calculated using Finkel's (1959) height-width formula for barchan dunes. Finkel's formula is $W = 10.34H + 4.0$. Table 1 shows the unfortunate result, which indicates discrepancies between the widths found from the height calculations and the widths found by direct measurement from the orthographic image. It is my belief that it is not possible to obtain good accurate measurements directly from the photograph and that another method be used in order to test the validity of the height calculations. Hopefully, it will then be possible to shed further light on the physics of the Martian dunes' formation and on what forces are presently acting on them.

TABLE 1
Comparison of widths found by calculation and by direct measurement of barchan dunes on Viking frame 524B21

Approx. sample no.	location of dune line	Calculated height	Measured width	Finkel width
735	90	23 meters	500 meters	250 meters
745	110	36	550	375
750	115	68	700	700
760	90	33	550	350
763	110	25	350	250
763	135	38	500	400
778	125	31	450	325
792	110	7	250	75
815	125	32	500	350
822	100	42	450	450
800	65	41	500	425
770	20	35	550	350
743	25	13	400	125
773	10	15	350	150

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MARTIAN VALLEY ORIENTATIONS AND REGIONAL STRUCTURAL CONTROLS

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Processes ranging from rainfall to basal sapping to surface runoff from seepage zones (Sharp and Malin, 1975) have been proposed to explain the origins of martian valley networks (Milton, 1973; Sharp and Malin, 1975; Pieri, 1976, 1980). Such formational processes, involve the movement of groundwater or surface water which would presumably be facilitated and directed by the existence of zones of structural weakness associated with faults or joints. Strong positive correlations between network orientation and regional joint patterns have been demonstrated for canyons in the Colorado Plateau (Laity, 1980) which are analogous to martian valleys in morphology and perhaps in certain aspects of their origin (i.e. basal sapping) (Baker, 1980; Pieri, 1979; Pieri et al., 1980). Thus, models for valley formation which invoke a lithospheric source (e.g. sapping/seepage) imply that the subsurface control of valley orientation should be strong (Sharp and Malin, 1975; Pieri, 1980).

In an effort to determine whether any correlation exists between valley orientation and structural landforms (e.g. grabens, scarps, mare ridges, lineaments), the orientations and lengths of these features were compared to the orientations and lengths of link segments comprising nearby valley networks (Figure 1). Three regions on Mars were selected on the basis of terrain type: (1) Margaritifer Sinus in the neighborhood of Nirgal Vallis representing Lunae Planum age cratered plains (Figure 1c and b); (2) Sinus Sabaeus near Flaugergues crater representing older heavily cratered terrain (Figure 1e and f); and (3) Sinus Sabaeus proper which is a composite of older heavily cratered terrain and younger intercrater plains (Figure 1e and d). Figure 1 (a through f) is a series of rose diagrams comparing the orientation and lengths of mapped structural features (Figure 1a, c, e) to nearby valley lengths and orientations (Figure 1b, d, f).

Figure 1a clearly displays the strong E-W trend of the numerous graben which exist between Nirgal Vallis and Valles Marineris. A corresponding trend is clear in Figure 1b and is due primarily to the orientation of Nirgal Vallis, generally parallel to the graben system. Also visible is a strong NE-SW structural trend with which there is little correspondence in valley orientation. This lobe corresponds to mare ridges which may be younger than nearby valleys. There is a major N-S trend in valley orientations, with no structural counterpart associated with Ladon Vallis which is quite old as evidenced by clearly superimposed large impact craters.

The heavily cratered terrain of Sinus Sabaeus (1e and f) shows two prominent trends (N 20° - 30° W and N 30° - 40° E) which appear in both valley and structural orientations. Old and perhaps exhumed valleys showing good directional correlation with structural topographic elements may argue for persistent, stable or ancient structural controls.

The region near Flaugergues crater (Figure 1c and d) composed of both cratered terrain and intercrater plains shows two major trends in structure orientation (N 20° - 40° W and N 20° - 40° E) but with only the former expressed in valley orientation. The NE-SW structural trend corresponds to mare ridges in intercrater plains, younger than the subjacent heavily cratered terrain in which the valleys are expressed.

Correlations exist in these data between the trends of structural features and valley orientation, however, in several cases structural elements postdate valley formation and show no correlation with valley orientations. It is felt that sun orientation while probably having a small effect does not bias the data strongly, particularly since about one-third of the data show clear east-west trends.

While this study is preliminary and of limited scope, it shows the coincidence between the regional orientations of structures such as grabens, scarps, structural lineaments, and mare ridges and valley networks. Further detailed work which addresses the local geological interaction between mare ridges and tributary canyons of Nirgal Vallis is underway. Preliminary geologic and geomorphologic sketch maps have been produced from high resolution ($\lesssim$ 40 meter per line pair) Viking images, which show the direction of tributary development to be correlated with the presence of mare ridges intersecting the valley at high angles. We conclude that on both regional and local scales subsurface structure has a strong influence on the orientations of neighboring valley networks. This observation is consistent with and suggestive of valley formation by groundwater flow by either seepage or sapping mechanisms.

Caption, Figure 1

Shown here are the orientations of valley link segments (b,d,f) as compared to the orientations of structural landscape elements (e.g. scarps, grabens, troughs, lineaments) (a,c,e). Locations are defined in the text.

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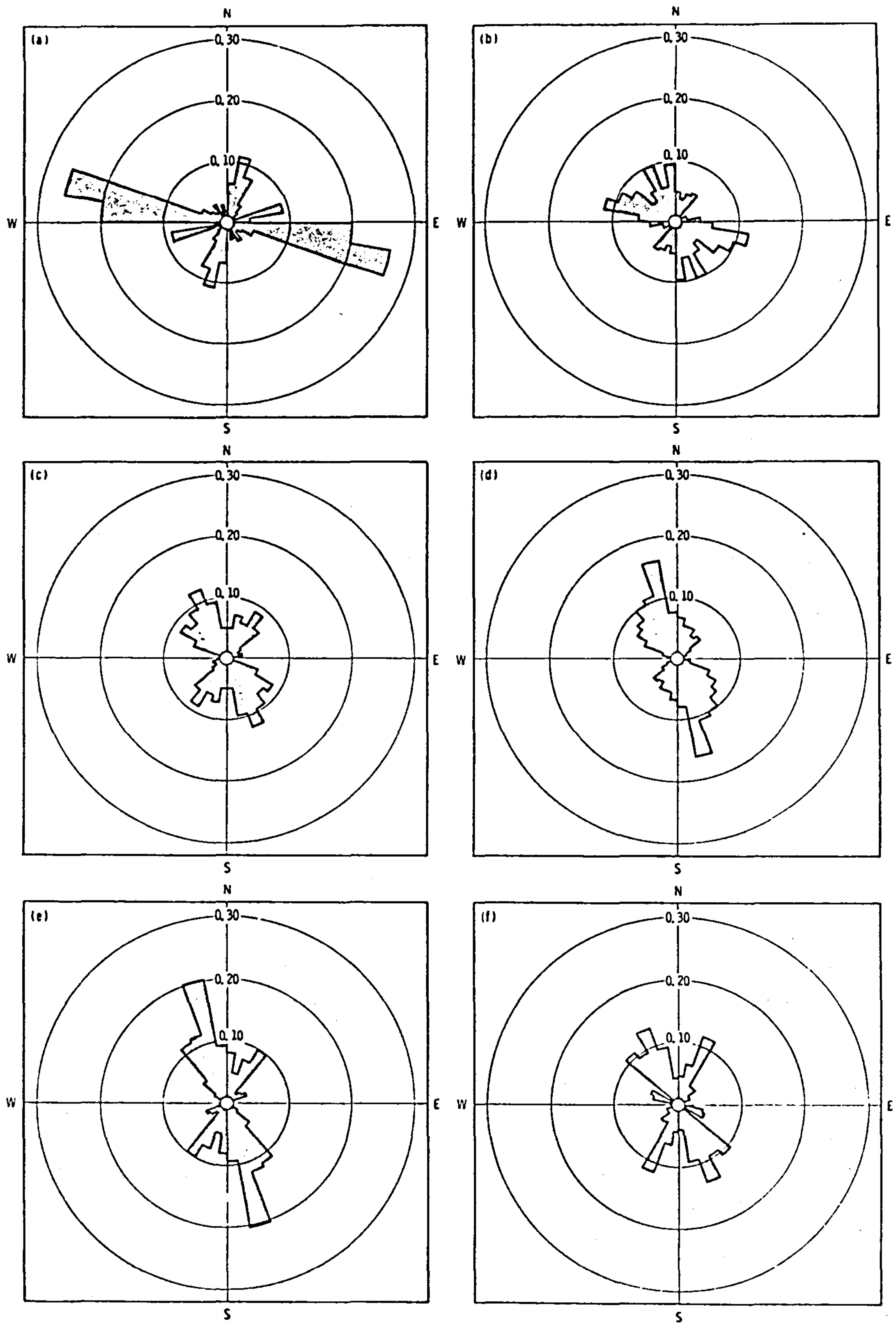
(a)
(b)
(c)
(d)
(e)
(f)
N
S
E
W
0.10
0.20
0.30

MOUNTAIN LANDFORMS ON IO

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An important discovery by the Voyager mission was the presence of large mountains on the surface of Io. The purpose of this investigation was to characterize these landforms in terms of their morphology, distribution and dimensions. Voyager 1 high resolution images (0.5-5 km./line pair) show that the planimetric shape of the mountains on Io are diverse: irregular, elliptical and ridge-like. The topographic texture of these features is very rugged; having been disrupted by fractures. The crests of the mountains are ridges, not isolated peaks, and steep walls or scarps usually form the mountain flanks.

The highest resolution images of a mountain are those of Haemus Mons, taken near the terminator. The topography of this mountain is controlled by lineaments forming parallel ridges and troughs which are probably fractures. These lineaments form two sets, intersecting at an angle of about 50°. A graben-like structure and a lineament in the adjacent plains parallel the two sets of mountain fractures. Although a pit crater occurs at the base of Haemus Mons, no volcanic landforms such as calderas or flows are observed. Where resolution allows, these same characteristics are also found on other mountains.

Thirty nine mountains were identified on Voyager 1 limb and terminator photography. These mountains were correlated with albedo features on full-phase images and then located on the Preliminary Pictorial Map of Io. Both their lateral and vertical dimensions were measured with respect to the mean limb and are minimum values since the mountains probably are a few degrees over or in front of the limb. The mountains range in height from about 3 to 13 km. and in width from about 6 to 190 km. These large dimensions indicate that the material has a high yield strength consistent with silicate material. Without exception, the mountains correspond with bright to moderately high albedo markings. This suggests they are coated with a bright material which may be frozen SO_2. Contrary to earlier reports,[1] these mountains seem to be uniformly distributed over the surface rather than concentrated in the polar regions. Furthermore, they appear to be isolated massifs rather than continuous chains, but some clustering probably occurs.

Mountains on the terrestrial planets are formed by three general mechanisms: impact, volcanism and tectonism. The origin of the mountains on Io is not clear from the limited data base available. However, it is not likely that they are the remnants of impact crater or basin rims because of their great height, uncharacteristic morphology and uniform distribution. Although features of unambiguous volcanic origin are lacking on the mountains, it is possible that such features have been rendered unrecognizable by fracturing and other types of disruptions such as mass wasting. The fractured nature of these mountains does suggest that tectonism has played a role in their formation. Possibly they are segments of the silicate crust which have been uplifted by tectonic forces early in the history of Io. In any event, any proposed origin of these features must take into account the following characteristics: (1) uniform distribution over the surface, (2) high to moderate albedo, (3) very large dimensions, and (4) the high degree of fracturing.

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RESULTS OF A PLANETARY GEOLOGY INTERNSHIP AT THE SMITHSONIAN INSTITUTION: A MINERALOGICAL ANALYSIS OF SAND SAMPLES FROM THE WESTERN DESERT OF EGYPT

by
Charles T. Herzig
1 August 1980

INTRODUCTION

Observations recorded by the astronauts during the Apollo Soyuz Test Project (ASTP) indicated that the color of desert surfaces varies both on a regional and local scale. A reason for these variations has been shown to be related to compositional changes in the exposed surfaces (1).

The Western Desert of Egypt was selected as a test site for the ASTP. Several field excursions have been made to the Western Desert for the collection of samples for ground truth measurements. Specific sites were chosen for a detailed mineralogical analysis of the samples collected from these localities. The purpose of this "expanded abstract" is to present an account of the work completed on these samples during a NASA Planetary Geology Internship at the Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. under the direction of Dr. Farouk El-Baz.

GENERAL SETTING

The Western Desert is a plateau of limestones and sandstones encompassing two-thirds of Egypt. There are seven major depressions in this desert and two topographic highs, the Gilf Kebir and Gebel Uweinat, in its southwestern corner (2).

Overlying the bedrock are bundles of sand dunes, with the largest accumulation, the Great Sand Sea, in the western central part of the desert. There are several types of dunes and the large north-south trending longitudinal dunes are the most prominent in the ASTP photographs.

STUDIED SAMPLES

Sand samples were collected from a wide variety of locations in the Western Desert. However, only seven sites were selected, on the basis of previous mineralogical analyses (3), for the detailed mineralogical study. These locations include the oases of Faiyum, Bahariya, Siwa, Dakhla, Kharga, Bulag, and the Great Sand Sea.

SAMPLE ANALYSIS

The sand samples were studied according to the accepted procedures of sedimentary petrography. The samples were sieved and separated into quarter phi units (0.00 - 4.00 + Pan) and a representative part of each size fraction was mounted in Lakeside 70 ($n \approx 1.54$).

The grain mounts were examined utilizing a Nikon polarizing microscope. The polarizing microscope was preferred over the binocular microscope because of the capabilities of the former to facilitate a more accurate identification of the minerals present.

The counting procedure consisted of a preliminary examination of the grain mounts, recording all identifiable mineral species present. One hundred point counts were made by traversing the slide linearly, where the grains were counted using the crosshairs as pointers. During the course of the preliminary identification, photographs were made of the sand grains. This was done in order to record any unusual features present, as well as the mineral species and representative features of the sample.

DISCUSSION

As expected, the examined samples consisted primarily of quartz and varying amounts of other minerals. However, the early stages of the analysis indicated that the point counts would not be as simple as identifying quartz and the other mineral species. Each sample contained a wide variety of quartz grains as well as calcareous grains, which constituted the second most abundant species. For example, the types of quartz present ranged from rounded to angular shapes; contained a wide variety of inclusions, such as rutile, tourmaline, apatite, zircon, and others, where the inclusions had different shapes and affinities for one another; and the quartz grains exhibited a wide variety of coatings. Whereas the angularity measurements and the type of inclusions were easily classifiable, the coatings presented a difficult problem. This is because the quartz grains had coatings that were multi-colored, varied in the area of the grain covered, and were of different varieties (hematitic and calcareous). Hence, this characteristic of the quartz grains was limited to a classification according to coatings being present or absent.

Other mineral species present were various types of calcareous grains, calcite, tests, gypsum, rutile, garnet, tourmaline, hornblende, zircon, staurolite, epidote, pyroxene(?), apatite(?), plagioclase, microcline, feldspars, kyanite, biotite, and opaques (ilmenite with some alteration to leucoxene). Some samples also contained large amounts of rock fragments in the coarser size fractions. It is interesting to note that this group of minerals, especially the heavy minerals, exhibited features that would be diagnostic in a provenance study. Several varieties of tourmaline and rutile were present, and some calcite grains exhibited an anomalous biaxial optic axis figure, which are indicators of a unique source rock. Also, the heavy minerals had different degrees of angularity, which is an indicator of transport distance in an eolian regime.

CONCLUSION

The data and observations from the mineralogical analysis of seven areas in the Western Desert of Egypt will provide information to facilitate a better understanding of the color variations observed in the desert surfaces in the ASTP photographs. The results will be useful to parallel studies of the spectral reflectance properties and the nature of the grain coatings of the same samples. It is apparent that the knowledge of the detailed mineralogy of the samples is necessary for explaining variations in the sands. If there is some relationship between the results of the spectral reflectance data and the mineralogy, then this relationship may be extrapolated to the deserts of Mars, due to their similarity with the Western Desert of Egypt (4).

Finally, it is recommended that more work be done on the inclusions in the quartz grains. Also, if samples were to be collected from rock outcrops in Egypt, a provenance study could be easily accomplished. This study would further enhance the results of studies on the transportation of the sands in the dry eolian regime of the Western Desert of Egypt. This in turn would further our understanding of transport and oxidation of particulate matter on Mars.

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ORIENTATION OF IMPACT CRATERS ON MARS. Melinda Hutson, University of Minnesota, Minneapolis, MN 55455 and Robert W. Wolfe, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.

Terrestrial and Lunar impact craters have been noted to depart from circularity. In some cases, the deviation from circularity reflects gross pre-impact structural characteristics of the terrestrial or lunar crust (Eppler et al.,). Meteor Crater in Arizona is a well-known example. The quadrate shape of the crater is related directly to joints on the Colorado Plateau (Roddy et al., 1975). Martian craters also depart from circularity. Therefore, one might expect that these deviations also reflect gross structural characteristics of the Martian crust.

We measured the shapes of 817 martian craters in the region from 0° to -30° latitude, tracing the crater rims of craters from nineteen 1:2,000,000 scale USGS photomosaic maps of Mars. Each crater outline was digitized and the first twenty harmonics of a Fourier spectrum, particularly the second harmonic phase angle (the long axis orientation) was computed (Ehrlich and Weinberg, 1970; Eppler et al., 1977). For each of the nineteen maps, a rose diagram was drawn by plotting the direction of the long axis on a polar co-ordinate graph in increments of 10 degrees.

In most cases, long axis orientation of the martian craters appeared to be nonrandom. Many of the craters within a map had long axes parallel to subparallel to each other. One clear example of this was the Memnonia quadrangle. The majority of the craters in this area had their long axes oriented in a range from 100° to 140°, or in a northwesternly direction. The majority of the craters in the southeast quarter of the Aeolis quandrangle have the same long axis orientation of 100° to 140°. The majority of the craters in the lower half of the Margarititen Sinus quandrangle, on the other hand, had their long axes oriented in an east-west direction in a range from 160° to 200°. There were also minor local orientation trends, in small areas of an individual quandrangle, and trends where the long axis orientations gradually increased or decreased in angularity in certain directions.

There needs to be additional studies to see if these orientations are reflected in other structures on Mars.

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SIZE-FRACTION ANALYSES OF MAUNA KEA, HAWAII SUMMIT SOILS AND THEIR POSSIBLE ANALOGY WITH MARTIAN SOILS

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INTRODUCTION. The Viking lander x-ray fluorescence spectrometers gave elemental analyses which suggest derivation of surface fines from mafic or ultramafic igneous parent rocks (1), such that soils developed on terrestrial basalts under dry, nearly abiotic conditions might serve as reasonable analogs of Martian soils. Ugolini(2) proposed soils from the summit region of the Mauna Kea, Hawaii volcano as such analogs.

SAMPLES AND METHODS. Two samples were selected from surface (upper ~ 12 cm) soils developed, respectively, on volcanic and glacially/fluvially reworked deposits near the Mauna Kea summit. The first (5B) was taken from Puu Poliahu, a tephra cone within the Waikahalulu Formation of the Laupahoehoe Group (3,4). The second (3B) was collected from a Makanaka Formation (also Laupahoehoe Group) deposit which is interpreted as outwash material (3,4) possibly produced by catastrophic flooding precipitated by melting of glacial ice.

Each bulk soil was separated into size fractions using a sonic sifter and ASTM sieves. After optical microscopic examination, portions of each fraction were crushed to pass a 30-μm sieve and analyzed by x-ray diffraction (XRD) and visible/near-infrared (VIS/NIR) reflectance spectrophotometry.

RESULTS AND INTERPRETATION. Sieve analyses (Fig. 1) show that soil 3B (outwash plain) contains appreciably more fine material than does 5B (tephra cone). However, $<$ 5 weight percent of either sample falls within the apparent silt-size range of Martian surface fines analyzed by the Viking landers (5).

XRD indicates that both soils contain similar relative abundances of primary igneous minerals (plagioclase, olivine, pyroxene, and spinels). Soil 5B also contains substantial amounts of secondary minerals including smectites and hematite. Furthermore, at least three XRD peaks from 5B show systematic increases in intensity with decreasing particle size (Fig. 2), indicating concentration of some (mostly secondary) minerals into small particles. In contrast, 3B shows no pronounced variation of mineralogy with particle size.

Two NIR absorption bands (1.4, 1.9 μm) of 5B (Fig. 3) are attributable to hydrous phyllosilicates (6) although 3B exhibits only incipient bands at the same wavelengths as would be characteristic of an unweathered basalt (7). Color differences between the soils (yellow-brown, 5B; gray-black, 3B) are substantial with 3B composed mostly of crystalline rock fragments and 5B composed of tephra fragments coated with weathering products as well as individual particles of secondary minerals (Fig. 4).

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CONCLUSIONS. Significant mineralogical differences can arise between soils developed on genetically and temporally related but depositionally distinguished basaltic substrates. Fluvially re-worked but little-weathered silt may be mineralogically similar to its parental material although unworked but significantly weathered materials may produce silt which is mineralogically distinct from its source. Consequently, compositions of silt-sized Martian soils, in general, should not be expected to reflect the compositions of their parental bulk soils or source rocks unless chemical weathering has not occurred. Most likely, a variety of soil types occur on Mars, representing a wide range in degree of weathering.

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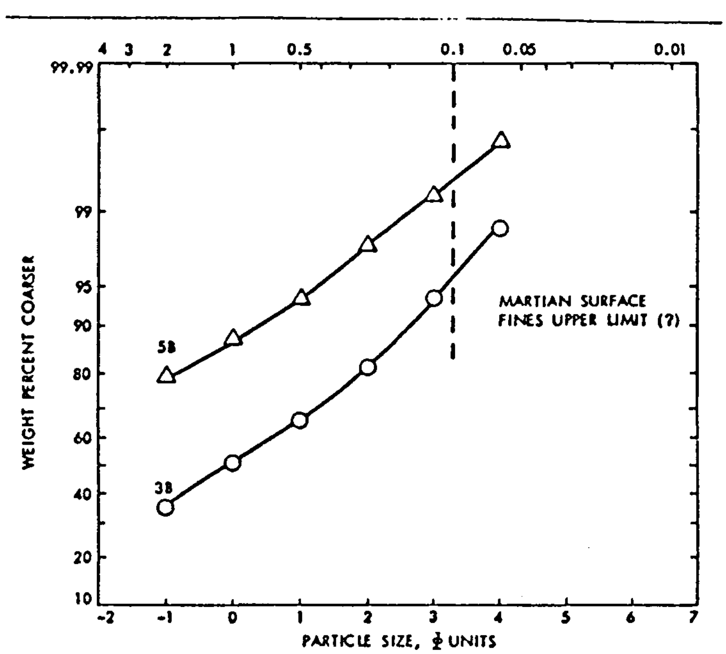

Figure 1. Particle-size distributions of two Mauna Kea summit soils compared with estimated (5) particle size of Martian surface fines. Upper horizontal scale is in mm.

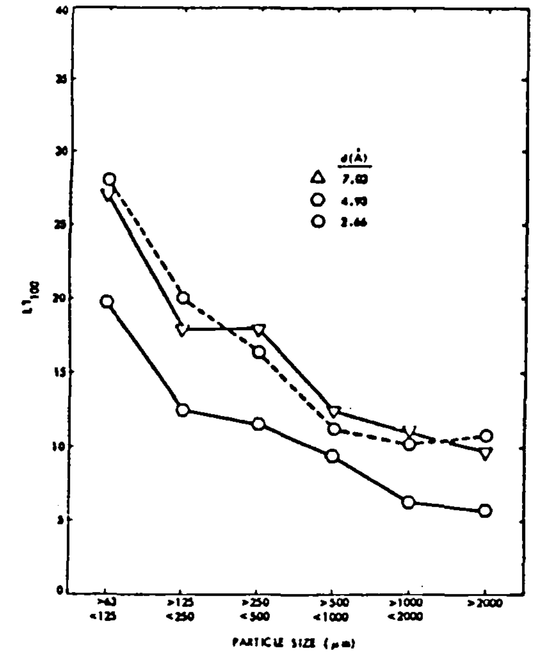

Figure 2. Normalized relative intensities of selected XRD peaks (7.03, 4.93, illite (?); 2.66, plagioclase or hematite) as a function of particle size in Mauna Kea soil 5B.

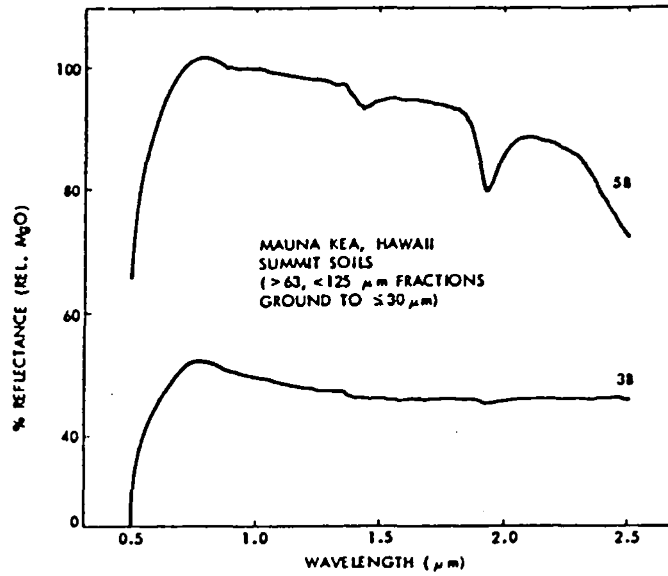

Figure 3. VIS/NIR reflectance spectra of Mauna Kea soils 3B and 5B (>63, <125-μm fractions).

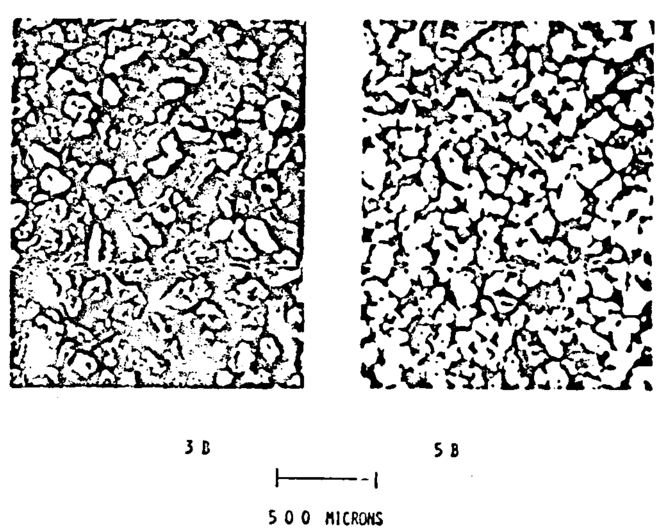

Figure 4. Photomicrographs of the >63, <125 - μm fractions of Mauna Kea soils 3B and 5B.

PARAMETRIC STUDY OF DUST FOUNTAINS

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INTRODUCTION

In the Mars regolith thermodynamics experiment currently taking place, a peculiar "problem" arose which may have implications for Mars. The formation of "dust fountains," an unexpected occurrence in the experiment, while worthy of study in their own right, might indicate a similar phenomenon on Mars. Such a phenomenon, as a transporter of small particulate matter into the atmosphere, could help to fuel the planet's dust storms. This paper is the result of "thought experiments," and observations made in a small chamber (25 cm x 40 cm x 3 cm) with one clear plexiglas wall. As a first attempt to understand fountain behavior, its purpose is to describe the interrelationships of the parameters affecting the channels and fountains, and discuss the potential for fountain formation on Mars.

HOW CHANNELS AND FOUNTAINS FORM

Dust fountains form when the pressure gradient across certain types of soil becomes great enough to form channels in the soil. Gas flow becomes concentrated in the channels, and shoots particles up above the surface in a plume, or fountain. The channeling phenomenon is one of fluid flow through a porous medium, when the inertial effects of the gas become significant. Gas flows under a pressure gradient in a porous medium. There are two ways a pressure gradient could form on Mars - - by a change in the atmospheric pressure, or by desorption of CO_2 by clay minerals as suggested by Fanale and Cannon (1, 2). Because adsorption is a function of temperature and pressure, an increase in surface temperature or a decrease in atmospheric pressure will cause the regolith to outgas, creating a pressure gradient, and enhancing channeling activity.

Observations seem to indicate four types of behavior in the montmorillonite, and montmorillonite/basalt mix studied as the pressure gradient across it is increased. The first two may be understood without considering the inertial effects of the gas, the latter two can not. The first behavior is that of normal flow through a porous medium. The second occurs when the hydrostatic pressure difference between some point in the soil and the surface is just greater than the overlying mass pressure. At this point, horizontal cracks appear, and the soil surface is upraised.

Channeling with subsequent fountaining is the third type. Here, the subsurface gas pressure, perhaps aided by the increased gas flow, becomes great enough to force soil out of the way and create a path to the surface. Once a channel is formed, the gas flow widens it, and straightens it out (i.e. makes it more vertical).

The fourth regime is that of fluidized particle movement. When the gradient becomes very great, the soil particles are pushed upwards with the gas in a fluid-like flow. This results in a "bubbling" at the surface, which is quite different from the distinct fountain events, and does not send particles up as high.

The inertial effects of the gas have not been studied yet in detail, but it would seem that a low permeability explains the connection between the cracks and the channeling. A highly permeable soil allows a greater gas flow, and would enter the fluid flow regime before building up great pressures at depth. Thus, a low permeability is a requirement for channel formation. Clays generally have low permeabilities, thus many types of clay might be expected to form channels. To the low permeability requirement, we may add two others. The soil particles must be small enough to move under the influence of a concentrated gas flow. And, the soil particles must not stick together with any appreciable force.

MEASURABLE PARAMETERS

The physical dimensions of a channel are dependent upon the mass flow through it. A channel will deepen until the mass flow at its bottom is large enough to elevate the particles. Gas will expand until its upward velocity near the edge of the channel is no longer enough to remove particles, thus the mass flow can be estimated from the width of the hole at the surface. Another measurable parameter, the fountain height, can be related to the gas velocity in the center of the hole, and thus to the mass flow.

The mass flow through a channel for a given soil is dependent on the depth of the soil. With an equivalent rate of pressure change at the surface, a deeper layer of soil is observed to have longer channels, wider surface holes, greater gas flows, higher fountains, longer lasting fountains, and a small surface distribution of fountains.

Minimum channel depths for a homogenous soil can be determined from the hole surface distribution. Since the pressure at the bottom of the channel will be nearly the same as the surface pressure, the minimum channel depth expected will be half the average separation of the holes. The actual hole distribution is determined by the pressure gradient at the time of channel formation. With a large gradient, many more channels per unit area are observed.

MARS

What are the chances for fountains on Mars? Ignoring desorption effects, consider a diurnal atmospheric pressure variation of 20 to 5 mb. This is larger than what is currently expected for Mars (many investigators). As an extreme case, suppose that the pressure at a depth of one meter remains at 20 mb when the atmospheric pressure has dropped to 5 mb. Comparing the overlying mass pressure

(= 1.5 g cm^{-3}) to the hydrostatic pressure differential, it is found that the former is greater than the latter at all depths. Thus, if channeling occurs only when the pressure differential is greater than the mass pressure, no fountain activity would be expected on Mars from diurnal pressure variations.

On the other hand, if Mars contains CO_2- adsorbing clays as Fanale suggests, fountains seem more likely. He calculates that a 10 meter depth of nontronite would release 10 g CO_2 cm^{-2} when heated from -110°C to -77°C (1). If the top 20 cm of soil released .02 g CO_2 cm^{-2} (one tenth as much per cm^3) uniformly over a ten hour period, the gas flow would correspond to an isothermal, steady-state pressure distribution (3) of 24 mb, much greater than the overburden pressure of 11 mb. While these are only rough calculations, they indicate that the potential for fountain formation on Mars exists if there are gas adsorbing clays in the regolith.

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FLUX OF WINDBLOWN PARTICLES ON MARS: PRELIMINARY WIND TUNNEL DETERMINATION

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Fundamental to the understanding of the aeolian regime on Mars is knowledge of particle flux in terms of particle size distributions and velocities as functions of free-stream wind speed and height above the surface. This knowledge is required for many problems dealing with the evolution of the martian surface, including the determination of rates of aeolian erosion. Although various theoretical approaches have been applied to the problem (White et al., 1979), an experimental approach is desirable in order to check theoretical results and to provide a broader data base for other studies of aeolian processes. Consequently, a general study of particle flux was initiated several years ago using the MARSWIT, the Martian Surface Wind Tunnel. Initial work involved perfection of various particle collectors that would be effective, yet not interfere with the flow of air and of the particles. Trial-and-error wind tunnel tests led to the design of triangular-shaped collectors, open at the apex (1 cm^2 collecting area), with flow-through 40 μm screens at the back and retainers to prevent particles from escaping; multiple collectors can be stacked to about 2 m high. Although some problems remain, the collectors allow a good assessment of particle size and number distribution as a function of height and free-stream wind speed. The second part of the problem involves the determination of particle velocity. Although high speed motion pictures provide some data, this approach is costly, time consuming for the amount of data returned, and the results are of marginal quality. Another approach uses a *particle velocimeter*; this device was originally developed by the U. S. Forest Service to measure velocities of blowing snow (Schmidt, 1977) and the design was modified for use in our wind tunnel. The velocimeter consists of a light source that produces a light beam perpendicular to the wind-stream, and two light-sensitive semi-conductors that detect the shadow of any intersecting particle as it crosses two separate portions of the light beam. A voltage is produced as each beam is interrupted; thus, particle velocity is derived from the time interval between the two pulses and the distance between the two light sensors. This distance was calibrated using wires of various radii spinning on a motor at known velocities.

An experimental matrix was developed involving: (1) *particle diameter* (760 mm, or "common" sand size and 92 mm, or the size most easily moved by lowest strength winds); (2) *atmospheric pressures* of 1 bar ("Earth" case) and 6.6 mb ("Mars" case); (3) *free-stream wind velocities* of 65 m s^{-1} (minimum Mars threshold) and 115 m s^{-1} (strong Mars storm) and 11.1 m s^{-1} (mild Earth storm) and 6.9 m s^{-1} (threshold "Earth" case); and (4) *height above surface* of 29, 71, 161, and 240 mm. Although not all combinations of variables have been run, enough experiments have been completed to show some interesting trends. Figure 1 shows the general increase in particle velocity with height above the surface, reflecting increasing wind speeds through the boundary layer, for the nominal Mars "sand" storm case. Note, however, that most of the particles have velocities *less than 20 percent of the free-stream wind speed*: similar runs for "Earth" conditions show that particles generally achieve velocities much closer to free-stream than on Mars (Fig. 2). Thus, although much greater wind velocities occur (and are required for threshold) under martian conditions, the coupling of the particles with the wind is much less, and the effectiveness of wind erosion would be decreased. Preliminary results for particle flux as a fraction of free-stream velocity under "Earth" conditions are shown in Figure 3, for two particle sizes. At the time of writing, insufficient data were collected for "Mars-cases" for comparison. However, using some preliminary results for flux in combination with the information on the velocity distributions and knowledge of wind strengths/frequencies from the Viking Landers enables estimates to be made for rates of aeolian erosion. These experiments will continue through the next fiscal year.

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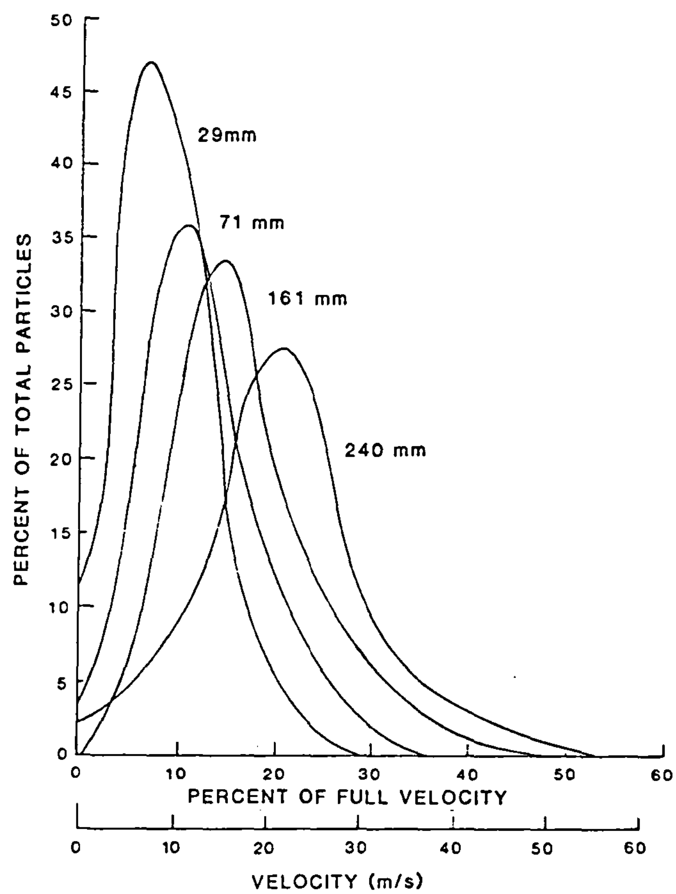

FIGURE 1. Velocity distribution for saltating particles under low pressure (Martian surface) conditions for four heights (29, 71, 161, and 240 mm) above the surface; velocities are shown as both percentage of full "free-stream" speed, and as actual speed in meters per second.

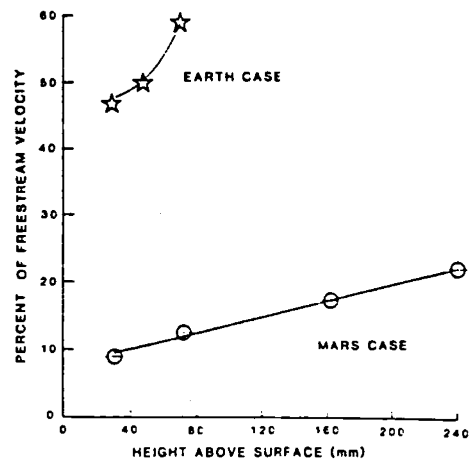

FIGURE 2. Particle velocity shown in percentage of free-stream velocity for "Earth-case" and "Mars-case" as a function of height above the surface; note that particles are more closely coupled to the wind on Earth than on Mars.

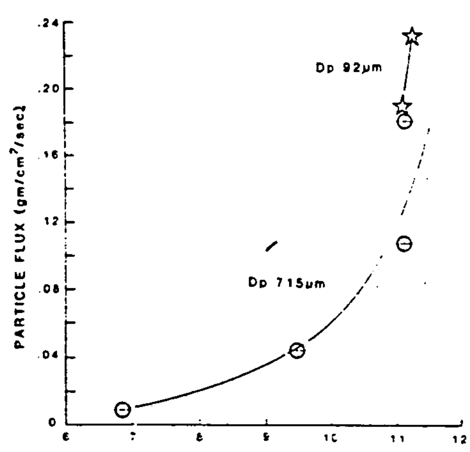

FIGURE 3. Particle flux for "Earth-case" for two sizes of particles as a function of free-stream wind speed.

A COMPARISON OF LARGE CRATER FEATURES ON GANYMEDE AND MARS

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Ganymede is the third of the Galilean satellites of Jupiter. Its surface is thought to consist of a water-ice and silicate mixture. The structures that are formed as a result of the cratering process in an ice silicate target have not been studied in detail. This report looks at three large craters on Ganymede and describes their external morphologies, textures and albedoes. Also, comparisons of these features are made with corresponding features on similar craters on Mars.

The craters studied on Ganymede were chosen based on clarity and freshness of features. All of the Voyager 1 and 2 picture frames of Ganymede were inspected for large fresh craters near the terminator or craters whose morphologies were otherwise distinctive enough to map. The three Ganymede craters chosen were all larger than about 50 km in diameter. The basic features that these craters had in common served as a model for choosing craters on Mars for the comparison.

The craters on Mars were selected based on the criteria that first, they exhibited the salient features that were found on the Ganymede craters, second, that they be of approximately the same size and third, that the features be of comparable resolution with those on Ganymede. Once these criteria were set the craters were searched for using 1: 1,000,000 mosaic maps of Mars. Three suitable craters were found. The craters were then inspected in more detail and mapped using Viking Orbiter pictures.

The descriptive maps that were prepared showed the surface extent of the features which were mapped as distinct units. The units were defined and delineated based on continuity of form, texture and albedo.

To a large extent it appears that the exterior ejecta of the Ganymede craters is modified by what seems to be the pre-existing terrain. The surface of Ganymede is dominated by two general types of terrain. One has come to be known as grooved terrain and the other as cratered terrain. The grooved terrain occurs as long bands which in general have parallel or sub-parallel grooves or furrows that extend along the length of the band. The bands also contain few craters. There is some variation in the form and arrangement of the bands. The bands are usually bilaterally symmetric but sometimes the sets of grooves do not extend all the way to the center of the band, leaving it essentially smooth there. The bands themselves may bifurcate, thin out and disappear, truncate other bands or cut across other bands. The bands are higher in albedo than the cratered terrain.

The cratered terrain is very much darker than the grooved terrain and consists of presumably very old material that is thoroughly cratered and pitted. It is disected into large and small, generally polygonal patches by the grooved terrain. This pre-existing material shows through the ejecta of two of the craters making it appear dark and rough in places and light and smooth or grooved in other places, corresponding to whether it is underlain by cratered terrain or grooved terrain.

The central pits of two of the Ganymede craters have large, smooth updomed constructive features in them. The Mars craters showed only one example of a constructive feature and in that case it was rough and irregular. The floors of the Ganymede craters were more domed than the Martian craters. Also, they had sinuous furrows which originated at the central pits and extended outward. These furrows were absent in the Martian craters studied. The Martian craters had raised central pit rims while the rims of the Ganymede central pits were even with the floor or only slightly raised. The walls of the Ganymede craters were thinner and more continuous in form than the Martian crater walls. The Martian craters showed much wider walls with extensive terraces, scalloping and blocky terrain associated with them. The Ganymede craters showed only minor wall failure.

The external ejecta of the Martian craters was highly eroded and indistinct so no comparisons of these features were made.

SURFACE FEATURES OF EUROPA AND GANYMEDE AND THE RELATIONSHIP TO THEIR EVOLUTIONARY HISTORIES

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The two most probable processes for forming surface features on Europa and Ganymede are convection and expansion. Early thermal models (Lewis, 1971) assumed conduction in the crust, not convection. Conduction alone would not result in any surface features. This model was further expanded by Consolmagne and Lewis (1976, 1978). However, Reynolds and Cassen (1979) showed the importance of convection in the crust. They concluded that the satellites, having undergone melting and differentiation, would now be totally refrozen due to convection.

Surface features from solid state convection depend on the crustal model used. With a rigid near surface ice layer, as suggested by Reynolds and Cassen (1979), both compressive and tensile tectonic features would be likely to exist. If convection continued up to the surface, the fracturing of a thin layer of hard ice at the surface could result in accumulations of this ice in zones of subduction. Sublimation may also play a part, resulting in the surface accumulation of meteorites that had become imbedded in the crust, much as occurs in the antarctic ice sheets in the zones of ablation (Cassidy, 1979). A very thick, rigid ice layer or the lack of convection would result in no surface features.

Voyager imaging has shown Europa to have striking linear features resembling cracks which occur over the entire surface. These features show no relief and are apparent only as albedo differences, the cracks being darker. Also irregular dark patches occur around the 'planet' often obscuring cracks which pass through them.

It is difficult to see how any process of convection at the surface could produce the features observed here, especially the cracks. They seem most logically attributable to the expansion of the surface that results from differentiation (Squyres and Shoemaker, 1979).

Expansion occurs when the denser polymorphs of ice, that exist within the homogeneous body, begin to melt into less dense water. Differentiation would result in the formation of an ice crust early on and this crust would expand as melting and differentiation progresses. Europa's high albedo (~0.7), highest for the icy satellites, suggests a very efficient differentiation. It can be concluded, therefore, that convection in the homogeneous body was not significant enough to prevent melting and differentiation as suggested by Parmentier and Head (1979).

A conspicuous aspect of European morphology is the lack of significant cratering. This suggests that its surface is the youngest of the icy Jovian moons. This is most likely the result of active erosion and is probably caused by sputtering (Lanzerotti, et al, 1978). Sputtering could have resulted in the erosion of tens of meters to kilometers of subsurface material (mostly ice). Ganymede is greatly different from Europa in its surface features. It shows no cracking but rather complex bands of ridges or grooves that form segmented, branching, somewhat linear patterns which often cross-cut one another. Individual grooves range in width from 5 to 15 kilometers and are only a few hundred meters high. The bands are from 10 to 100 kilometers wide and range from 10 to 1000 kilometers in length. The bands separate older irregular polygons of darker, heavily cratered terrain. The grooved terrain is estimated to range in age from 4.0 - 3.5 billion years based on crater densities (Squyres and Shoemaker, 1979). It has also been concluded that the cause of the grooved terrain is tensional stress (Smith, et al, 1979; Squyres and Shoemaker, 1979). Squyres and Shoemaker attribute the tensile stress to the expansion of the crust due to differentiation. Another possibility is that tensile stresses developed as a result of convection in the crust below a rigid ice layer. However, the expected compressional features expected with this model are not observed.

Thus, the surface features of both Europa and Ganymede are seen to be most likely the result of expansion during differentiation rather than convection. Since the grooved terrain on Ganymede is expected to date from this time, when convection was just starting, any convection surface features that occurred should still be evident, just as the grooved terrain. That there are none observed indicates that convective surface features never existed. This requires that either convection never occurred, or that there has always been at the surface a rigid ice layer thick enough never to have been affected by the convective stresses below.

Reynolds and Cassen (1979) have called for a rigid surface ice layer which would resist convection due to low temperature (~100° K) and high viscosity. If thick enough, it would not show any surface features from convection. Another consequence of a rigid layer of surface ice has to do with the rate of topographic relaxation. If the surface ice is not rigid then any topographic relief would be reduced by creep deformation in less than 10^6 years (Johnson and McGetchin, 1973) assuming a higher surface temperature of 134° K. However, the grooved terrain, if the period of formation has been correctly estimated, formed relatively early in the history of Ganymede. It shows little if any signs of creep relaxation. It is apparent that creep deformation must not have been significant since the time of formation of the ground terrain and therefore for most of the history of the satellite. Also, craters on the grooved terrain are well preserved (Smith, et al, 1979) showing that little cold flow has occurred since the formation of the grooves.

However, degraded craters are observed on Ganymede in the heavily cratered terrain and have been attributed to creep deformation. It is possible that degradation is due to sublimation of the surface ice, but this would also degrade the grooved terrain and is therefore unacceptable for the same reason as creep deformation.

Since no process for crater degradation can have been in operation since the formation of the grooved terrain, the process or processes responsible must have been active only before groove formation and therefore before differentiation. Creep deformation would occur if the surface temperature of the satellite were higher than the present temperature. Johnson and McGetchin (1973) used a surface temperature of 134^{o} K (based on infrared brightness temperature) to determine the viscosity from which they showed that creep deformation would occur. The occurrence of undegraded craters and degraded grooves indicates a period when the satellite was still a homogeneous body during which the surface temperature was higher than at present. Additional sources of heat could be from accretion, higher orbital eccentricities, and the higher than present energy output of Jupiter. The temperature rise would not have to be great (around 34^{o} K to reach Johnson's and McGetchin's value). Craters formed during this period would be degraded in short order. As time passes, the surface temperature falls and craters formed are degraded more slowly. When differentiation occurs the surface temperature becomes too cold to allow creep deformation. This would explain the occurrence of degraded craters in the older, heavily cratered areas and the undegraded craters on the grooved terrain.

The possibility that sublimation has played an important role in the development of surface features requires further comment. A likely feature associated with sublimation would be the accumulation of silicates at the surface. As the ice sublimates, imbedded silicates would be left behind forming a 'reg' deposit. Sputtering would result in similar accumulations. The surface albedo of Ganymede is around 0.4. Just under the surface is relatively clean ice as evidenced by impact craters. This accumulation of dark material at the surface has been attributed to a build-up of meteoric particles and dust. However, Europa, which has been shown to have a greater 'dusting' rate (Smith et al, 1979) has an albedo of around 0.7. If it is assumed that the albedo of Europa of 0.7 is due to the build-up of meteoric particles (therefore assuming total ice-silicate differentiation) then the darker appearance of Ganymede could be due to a 'reg' deposit. Since sputtering is not assumed to be important for Ganymede, then sublimation should be the cause of the accumulation. This would require a less-than-total ice-silicate differentiation.

The period of 'reg' formation must have been restricted to an early time before the formation of the grooved terrain. Sublimation would tend to degrade the grooved terrain, just as creep, and since this has not happened, sublimation can only have been important early in Ganymede's history before differentiation. As the grooves formed ice from below the 'reg' would mix with the silicates resulting in the somewhat higher albedo of the grooved terrain. Cratering since then would reveal fresh ice from below and no new 'reg' would begin to form on the fresh ice. If sublimation has continued since then, it has been at a much reduced rate.

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REPORT ON MARS ATMOSPHERE-REGOLITH INTERACTION EXPERIMENTS CONDUCTED AT THE JPL MARS SIMULATION CHAMBER, JUNE-AUGUST 1980

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The sublimation and condensation of Mars CO_2 polar caps due to seasonal insolation changes causes major (up to 40%) variations in atmospheric pressure (Hess et al, 1977). This variation has been quantitatively modeled by Davies et al (1977) and Pollack (1979). The predictions of these models are generally concordant with Viking lander meteorological experiments (Hess et al, 1977). However, there is a considerable amount of uncertainty in these models, and it is possible that effects other than exchange with the polar caps may significantly affect both the amplitude and phase of the pressure variation. One such effect is adsorption onto the regolith (Davis, 1969; Fanale and Cannon, 1971, 1974, 1978). If the atmospheric pressure wave penetrates deeply enough, the regolith may act as an isothermal buffer (here we assume that the pressure wave penetrates much deeper than the thermal wave). This effect is caused by the increased population of adsorbed CO_2 on the grain surfaces due to the increases in pore pressure. Alternatively, if pressure wave and thermal wave penetrate about equally, the regolith may act as an isobaric buffer. In this case, the changes in the adsorbed population is due primarily to the temperature changes. It has been argued, however, that the penetration of CO_2 would be so small that these effects could be ignored (Toon et al, 1980). Theoretical prediction of the depth of penetration is hampered both by our lack of knowledge of Martian soil parameters and by the complexity of calculating the diffusion rate through a highly adsorbing medium. Therefore an experimental investigation is desirable.

An apparatus was assembled to test CO_2 penetration through a cold, highly adsorbing soil and to study several other phenomena having to do with soil volatiles on Mars. The cylindrical, stainless steel chamber (61 cm in diameter by 20 cm in height) is encased within an insulated box. The large size and thermal feedback mechanism (see below) reduces wall effects. The soil partially filling the chamber is similar to Martian soil analyzed at the Viking lander sites in that it is primarily a fine montmorillonite. However, it was discovered after extensive soil preparation (drying, sizing, and dehydrating) that the soil density had been reduced to 0.6 g/cm^3, considerably lower than the 1.2 g/cm^3 density of Martian soil. It was decided to go through with the experiment as a test of the apparatus and data handling techniques, and as a first approximation to Martian soil data. The experiments will be repeated at a later date with soil of more reasonable density. The outside of the chamber is temperature controlled, and six stainless steel pressure and temperature sensitive probes extend into the soil at various depths. This eliminates the thermal boundary effects of the wall.

Different gases (CO_2, N_2, He) can be introduced into the chamber at measured input pressures and flow rates. The chamber is first evacuated. Then as the gas is let in, the total amount admitted is recorded, as well as the pressure as a function of time at each depth. The latter measurement gives data pertaining to the effective gas permeability, while the former allows us to calculate the amount partitioned into the adsorbed phase. N_2 and He were used first, since they are very weakly adsorbed. Therefore, when the CO_2 is run, especially with the soil cold, the effects of adsorption should be readily separable.

The data treatment is as follows:

1.) Fitting the pressure data with smooth curves.
2.) Finding an empirical equation to fit the curves.
3.) Comparing the equations with any theoretical approximations that can be derived.
4.) Deriving parameters useful as diffusion constants.
5.) Comparing these with:

    a) the Toon et al (1980) a priori calculation,
    b) our expectations based on the physical parameters of our soil.

Using these results, we will then try to predict the effect on the season pressure variation on Mars.

We have fit an equation to the N_2 runs and are now at the stage of examining its form. Our current "best fit" empirical expression for pressure as a function of depth and time is:

$$P(d,t) = P_s - \beta \exp - \left(K \frac{t}{\sqrt{d}} \right)$$

where P_s is the surface pressure (held constant after the start of the run), and β and K are parameters used to fit the curves. This equation is similar in form to the amplitude dependence of a sinusoidal wave diffusing into the soil, so we are confident that a diffusion constant can be extracted from our numbers.

After suitable equations are obtained for CO_2 as well, the data treatment will proceed as previously outlined. Clearly the bulk of the work is yet to be done; the Martian soil thermodynamics tests will not be completed for some time.

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THE EVOLUTION OF OLYMPUS MONS

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During the eight week internship in Flagstaff, I participated in a variety of projects and independent studies. However, I worked primarily with Dr. Elliot Morris on questions concerning the evolution of Olympus Mons. What follows is an extended abstract of this research.

Olympus Mons is perhaps one of the most amazing features on the planet Mars. The largest volcano yet discovered on any of the inner planets, it records a tremendously effusive period of volcanic activity in the Tharsis region. Many problems concerning its structure and evolutionary history remain, despite the thorough coverage of the area by the Viking Orbiter spacecrafts. One of these is the question of the origin of the unusual scarp which rings the base of the massive shield. Another is the delineation of a flow history and stratigraphy on the flanks.

The scarp ranges in height from 2-4 km and is irregular in shape and orientation. It is frequently draped by young flows which completely subdue the sharpness of the cliff. Landslide and slump modification has occurred in most areas; the scarp has almost certainly receded summitward from its original position. The steep, distinct portions of the scarp are most prominent in the NW and SE quadrants of the volcano.

Those who have worked on the volcanic interpretation of Martian terrain have offered several mechanisms for the formation of the scarp. These include erosion by wind or water, erosion of pre-Olympus Mons substrate and collapse, subglacial eruption, simple landsliding, and others. None of these approaches completely explains all of the dramatic features of the structure we see today. It is difficult through these models to account for the tremendous volume of material that would have had to be transported by an unknown erosional agent. Additionally, none of these mechanisms adequately explain the scale and spatial relations of the scarp. One very different mechanism for the formation of the scarp involves normal faulting that is directly related to the construction of the enormous shield and subsequent crustal deformation. Observations of the structural features of the flanks and scarp lend support to this idea. Some of the more important observations are listed below:

1. A roughly concentric ridge and fracture system occurs on the flanks of Olympus Mons. These could be indicative of thrust motion which occurred during subsidence of the volcanic pile.
2. There is general agreement of the linear portions of the scarp with the orientation of a regional fracture system.
3. There exists an annular depression at the base of the scarp. It is as if the surrounding terrain had been warped downward towards the volcano.
4. The edges of the flanks dip summitward; that is, the volcanic shield appears bowed upward adjacent to the scarp.

Briefly, the normal faulting episode can be described as an elastic response of crustal material to imposed stress. The loading of the region with large amounts of Olympus Mons basalts occurred by most estimates over a relatively short period of time. As the shield grew, a "sagging" of the crust beneath the load would occur. Close to the center of the cone, there would exist a room problem as summit area material collapsed downward upon a less rapidly subsiding flank--the result would be thrust faulting concentric to the center of mass. At a distance "x" from this center, determined by the thickness and strength of both the Olympus Mons and platform material, this downwarping would reach a point where the vertical stresses decreased beyond some critical level. A complex combination of both horizontal (related to the integrity of the surrounding terrain) and vertical stresses could cause a brittle fracture here, the remnant of which we see today as the scarp. Rebound of the margins of the shield adjacent but upslope (summitward) of the fracture would deform the strata in a concave upward direction. Terrain on the opposite side of the fracture could conceivably subside due to the tremendous withdrawal of material during the early eruptions, as well as in response to such a change in the state of stress.

There remain many details of this mechanism to be worked out by such methods as numerical modelling of similar conditions. A knowledge of the flow stratigraphy and evolution in time as well as in space of the Olympus Mons shield would facilitate further study of this hypothesis.

Attempts to develop a sequential eruptive history have been made by many investigators. These have been in general unsuccessful due to poor picture resolution, cloud cover, and the confusing morphology of flow features on the sides of the volcano. The mapping of different units based upon crater counting turns out to be statistically unreliable, for the number of significant craters is too low. In an effort to get around these difficulties, use of color ratioing techniques to enhance unit boundaries was attempted. The premise was that different compositions, ages, or states of degradation would be brought out by looking at certain color responses. A color composite of the Olympus Mons region using the RED, R/V, and V/R responses was developed at the Image Processing facility in Flagstaff.

From this base, discernible color "units" were mapped and an attempt made to correlate boundaries with physical features visible on the black and white orbital photography. Crater counts were done to perhaps substantiate, although not conclusively, these boundaries. Both checks were almost completely unsuccessful. It is more probable that the particular ratios used were more sensitive to water content and lighting conditions than any other factor, and thus basalt unit boundaries would not be enhanced. However, there should be more work done using this technique; some meaningful discoveries were made.

As a part of the cross check with the black and white photos, a high resolution mosaic of Olympus Mons was constructed. Several small patches ($\approx 100\ km^2$) of bright, smooth material were isolated on the consistently cloud-free SE flank which in a crude way did correspond to bright patches prominent on the color composite. A more careful look indicated that these patches indeed appeared to be older surfaces which remained topographically higher than the younger flows which streamed around it. Their elongated morphology and generally higher crater counts (as averaged over a much larger area containing these patches) supported this hypothesis. Such patches were also found along the upturned edges of the scarp. Large blocks of bright, stratified material were free of the rivulet-like flows that drape most of the flank surface. Indeed flows were seen to veer around the blocks. Thus, a basis for distinguishing at least two surfaces distinct in time was established. Further work must be done to search for similar surfaces elsewhere on the volcano.

Finally, a fairly good correlation was found between fractured portions of the volcano's flanks and lower crater counts. This supports the idea that some of the most recent flows on Olympus Mons originated along these fracture planes. This data agree well with earlier conclusions by other workers about the variation in age based on crater counts. Further analysis of this will hopefully shed light on the implications for a more general understanding of the history of Olympus Mons.

While these projects took up the majority of my time, I also engaged in several independent studies. These included an introduction to the theory and practice of radar interpretation, familiarization with the Galilean satellites geology and photography (especially Io), and participation in a lecture series on image processing techniques, organized by Dr. Morris and his colleagues. In addition, I spent time observing the photo lab in operation and talking with other scientists about their work.

The Search for Sun Dogs on Mars

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Sun dogs, or parhelia, are bright spots that appear on either side of the sun at the same elevation as the sun. On Earth, sun dogs are caused by H_2O ice crystals in the atmosphere. Whenever there are large numbers of hexagonal plate crystals in the air, with their short sides vertical, sun dogs appear. Each crystal acts like a prism; light from the sun strikes it and is refracted. Sun dogs form at the angle of minimum deviation for a prism, which is also the point of maximum light. The equation of minimum refraction is as follows:

$$\sin\left(\frac{d + a}{2}\right) = n\left[\sin\left(\frac{a}{2}\right)\right]$$

where a is the prism angle, n the index of refraction, and d the angle of minimum deviation. This equation for minimum refraction is valid only for rays in the principal plane of the prism. For sun dogs this only occurs when the sun is on the horizon. When the sun is above the horizon the sun's rays strike the ice crystals inclined to their principal planes. The net effect is to increase the effective index of refraction for the projection of the ray in the principal plane. Thus with higher sun elevations the angular distance from the sun dog to the sun increases. The sun dogs still appear at the same elevation as the sun. Using the above equation for H_2O ice, n = 1.31 (yellow light), and a = 60°, thus d is 21°50'. Tabular or columnar H_2O crystals form with right angles, so there exist water sun ice dogs for a = 90°. These form at 45°44' away from the sun (n = 1.31). Sun dogs may be colored, too, due to the change in the index of refraction with wavelength, with red closest to the sun, blue farthest away.

If there is no preferred orientation of the crystals, as in cirrus type clouds, then a halo is formed. Halos of both 22° and 46° angular radius can appear. This halo may be colored, too, with the inner part red and the outer part blue. Unlike sun dogs, the halos occur at the same angular distance regardless of how high up the sun is, as they are formed by crystals with randomly oriented principal planes.

On Mars there exists the possibility of sun dogs and halos formed by either H_2O or CO_2 ice. Unfortunately the index of refraction of solid CO_2 is not well known. An approximate value from some sources is 1.38 with an uncertainty of ± 0.05. Frozen CO_2 can form cubic crystals with prism angle 90°, so these CO_2 crystals would cause either sun dogs or halos at 64°45'. But a slight change in the index of refraction will change the position of the sun dogs/ halos greatly. For example, if n = 1.40, they then form at 73°44', or if n = 1.36, they then form at 58°10'.

Evidence of sun dogs on Mars would be useful for several reasons. It would show that large quantities of CO_2/H_2O crystals are present in the atmosphere at certain times. The crystal shapes would also be known.

The difference between a sun dog or a halo would indicate the crystal orientation. CO_2 sun dogs would provide a good value of the index of refraction of CO_2 under Martian conditions.

The search for sun dogs was made using Viking lander images. The Lander cameras form images by reflecting light from the scene onto one of 12 photodiodes. The photodiodes in turn convert the light into an electrical signal that is then digitized. Thus, each image is an array of numbers called picture elements. The end product is called a camera event. To make a color camera event, each line is viewed in turn by a blue, green and red photodiode. Infared camera events are also composed of three images of the same scene, each image made by a photodiode with a different effective wavelength in the infared. High resolution camera events are made using a broad band photodiode. All three types of camera events were used in the search.

First it was decided to look at all camera events that contained any part of the sky from 20° to 90° away from the sun when the sun elevation was lower than 15°, and that contained the elevation of the sun when the image was made. The 20 to 90 degree span was to try to catch both H_2O and CO_2 phenomena, even with the uncertainty in the index of refraction of CO_2. A low sun elevation would provide the longest path through the atmosphere and thus increase the probability of refraction. There were 60 camera events that qualified.

As time allowed, more images were searched. First high sun, morning camera events of the first summer were checked to see if the summer morning H_2O ice fog was causing any sun dogs or halos. 16 images met this requirement. At the same time Lander 2 autumn camera events were included to try to catch the sun shining through the polar hood clouds. Also, refraction phenomena could possibly be caused by atmospheric ice that was deposited during the following winter. There were nine such camera events. Finally, it was decided to search all camera events that contained the right azimuth for sun dogs regardless of sun elevation or season. This last group had a total of 109 camera events in it. Due to a lack of time, not all of these images were checked.

The images were searched for sun dogs at the Computer Graphics Lab at JPL. For each horizontal line of picture elements in the image, a graph of intensity as a function of azimuth was displayed on a CRT. An increase in intensity with distance from the sun, as opposed to the normal decline of intensity, would represent a sun dog. The entire sky portion of each image was searched. A display of the numerical values of the picture elements in a given area could be done if further information was desired.

On some, images noise was a problem. Occasionally it was necessary to use a computer program that did a vertical average of the picture elements in a defined box, to see if a horizontal variation in intensity was real.

To the level of detectability of the Viking lander cameras, no sign of either sun dogs or halos were seen. A total of 110 camera events were checked. 53 of these were either totally or partially saturated. Noise was a problem in 14 camera events. In 58 camera events either the point 22° and/or the point 46° away from the sun was present; the point 65° away from the sun was present in 35 images. At Lander 2, eight camera events that had the desired azimuth in them were images of the back of the S-band antenna. Of the 18 summer morning camera events, nine were good for H_2O ice refraction phenomena, 12 for CO_2. There were five camera events that were useless due to missing lines.

From this search alone it is not possible to conclude that there are no sun dogs on Mars. It is possible that they are there but were not captured in Lander images. There is also the chance that the sun dogs were missed because of data saturation. That is more possible for the sun dogs at 22°, as they form closest to the sun of all the sun dogs.

For the CO_2 sun dogs there could be two additional reasons for failing to observe them, even though the crystals are present. One could be that the index of refraction of solid CO_2 is too high. If the CO_2 crystal is cubic, and the index of refraction is greater than 1.414, then any ray striking the crystal will suffer total internal reflection. Another possibility is that the CO_2 condenses on already formed water crystals. If the H_2O part of the crystal is significant, then no sun dogs will be seen, even though the CO_2 does make the cubic crystal. Most rays striking it will go from air to frozen CO_2 to frozen H_2O and out again. Thus cubic CO_2 crystals may be present in large quantities without forming sun dogs.

Of course, the necessary H_2O and CO_2 crystals could be not present. At least the search shows that sun dogs are not a common or easily visible phenomena on Mars. This implies that for the days good images are available an upper bound can be placed on the quantity of sun dog forming crystals.

Acknowledgments

This work was done while I was a participant in NASA's Planetary Geology Intern Program. Steve D. Wall was my advisor at JPL. The suggestion to search for sun dogs on Mars was made by Paul Doherty of Oakland University, Rochester Campus, Michigan.

A Determination of Important Near Infrared Band Passes for Distinguishing Compositional Units on the Moon

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Introduction

This Project was designed to examine the near Infrared, (.6 - 2.5 micrometers), telescopic lunar spectra in detail. Its purpose was to determine the important band passes in this region that may be used to enhance lunar spectral imaging as a technique for distinguishing lunar compositional units and investigating their distributions on the moon.

Methods

Relative reflectance, residual absorption and absolute spectra were divided into four lunar morphological types based on where the spot was located on the lunar surface. These 'types' included Terra Craters, Terra, Mare Craters, Mare and Transitionals. Relative reflectance spectra were then qualitatively examined to determine the important spectral features for quantification. Residual absorption spectra, with their continuum slope removed, were the easiest spectra to use for quantitative measuring and analysis of important spectral parameters. These important parameters could be interpreted in a direct mineralogical sense.

Results

Three parameters were quantitatively measured. These included the 1.0, 1.2 and 1.5 - 2.0 micrometer wavelength features. Data analysis and reduction involved the plotting of three frequency distributions and six scattergrams. The three frequency distributions considered the 1.0 micrometer width/depth ratio, the 1.2 micrometer width/depth ratio and the 1.5 - 2.0 micrometer slope depth. The six scattergrams compared these and other measured features. Each of these graphs was examined visually to determine groups or clusters of spectra within the major morphologic types. Thus, each graph had a set of groups associated with it that represented clusters of spectra. A computer program was designed to search for reoccuring groups in each graph and to determine significant spectral combinations. Results showed that many of the combinations of spectra determined both visually and by the computer proved to be significant and followed previous results found in the literature. Some, however, were unexpected. A significant finding was the distinction between Flamsteeds A, B and F western basalts and the MS 2 eastern basalts all of which had previously been classified as mISP (Pieters, et. al. 1980). Another unexpected finding was the grouping of the eastern Mare Crisium 40 and 41 areas with the western Flamsteed A. More work is needed before the significance of the latter case is known as their spectra differ largely in the 1.2 micrometer width and depth and in their continuum slope values although they are quite similar in the 1.0 and the 1.5 - 2.0 micrometer parameters.

Because many of the results agree well with the previous literature, it is safe to assume that the chosen 1.0, 1.2 and 1.5 - 2.0 micrometer features are important for the distinction of lunar compositional units. Therefore, wavelength bands around six points that characterize each of these features were determined, (see Table 1). These represent the important band passes that should be used for lunar spectral imaging in the near infrared as a technique for distinguishing lunar compositional units. Although there are cautions in using these methods, with a finite number of band passes to choose from, these points will adequately discriminate the primary units of the lunar surface.

TABLE 1

CHARACTERIZING WAVELENGTH BANDS

Morphologic Types	Wavelength Bands (micrometers)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Terra	.76-.78	.91-.94	1.07-1.14	1.30-1.33	1.44-1.58	1.91-2.00
Terra Craters	.76-.80	.91-.97	1.04-1.17	1.31-1.34	1.45-1.58	1.94-2.00
Mare	.73-.80	.94-1.01	1.10-1.23	1.26-1.33	1.41-1.62	1.88-2.00
Mare Craters	.73-.79	.94-.99	1.14-1.24	1.25-1.39	1.46-1.59	1.92-2.00
Transi-tionals	.74-.79	.92-.99	1.01-1.20	1.28-1.32	1.45-1.59	1.94-2.00

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The Discovery of a Correlation between Near Infrared Continuum Slope Values for the .75-1.5 and 1.5-2.5 micrometer Wavelength Regions

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Introduction

This paper discusses the discovery of an apparent correlation between the near infrared continuum formulated by Pieters, et.al., (1980) and a new continuum fit that covers a spectral range between 1.5-2.5 micrometers.

Procedure

Several spectra of returned, apollo laboratory samples were examined with respect to their continuum slopes between .73 and 1.5 micrometers and 1.5-2.5 micrometers. For the 1.0 micrometer slope, a line was fit around .73 micrometers to a point tangent near 1.5 micrometers in a manner similar to Pieters, et.al., (1980). In the 2.0 micrometer region, tangent points on either side of the 2.0 micrometer absorption were determined and a line was then fit between these two points. Three graphs were made that compared the continuum slope values of the two wavelength regions for lunar soils, lunar breccias/igneous rocks and magnetic/ non-magnetic separates of lunar soils. Determination of a least squares fit for each graph followed.

Results

The graph that compares the continuum slope values of the 1.0 and 2.0 micrometer regions for lunar soils shows that there is a straight line correlation between the two values. Some points, however, do not follow this straight line distribution. Apollo 16 soils mainly follow the least squares line. Apollo 14 and 15 lunar soils also lie on this line although they have greater continuum slope values than Apollo 16 soils. Apollo 17 samples, however, are erratic in their distributions.

In the graph that compares the continuum slope values of the lunar breccia/ igneous rocks, the line that represents the least squares fit was determined for all positive values only. A less noticable, but distinctly linear trend between the two values exists. Apollo 12 samples cluster together with predominately negative 2.0 micrometer slopes. Similarly, Apollo 11 samples have greater continuum slope values in both regions than do the other breccias or rocks. More importantly, Apollo 12 soils follow the general trend outlined above but their breccia/igneous rocks do not. Overall, the best fit line for breccias/igneous rocks has a smaller slope value than that for soils.

Because of the lack of information, the graph depicting continuum slope values of the 1.0 and 2.0 micrometer regions for magnetic and non-magnetic separates of lunar soils cannot be adequately assessed.

It is evident from the presented data that there is an apparent correlation between the continuum slope values for the 1.0 and 2.0 micrometer spectral regions. As a result, there is a possibility that a continuum slope could be estimated for that part of the telescopic spectra beyond the 2.0 micrometer wavelength that is affected by a thermal component.

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The Voyager Project

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In August and September of 1977, two spacecrafts were launched on a journey that would take them out of our known solar system. It's main objectives were encounters with the Jupiter and Saturn planetary systems.

Aboard each spacecraft, is a Science Scan Platform upon which the sensors for the Imaging Science, Infrared Radiation, Polarimetry and Ultraviolet Spectroscopy Investigations are mounted. This platform is mounted to the polygonal 10-sided main body of the craft by a boom. This boom also serves as a mount for the Plasma Particle, Low Energy Charged Particle and Cosmic Ray sensors.

During cruise and especially encounter phases, the incoming data is monitored, assimilated and then analyzed for anomalies or unexpected results. These anomalies manifest themselves as mechanical and/or telemetry failures. One such mechanical failure was the Scan Platform "Creep" anomaly. Here the Science Scan Platform would "creep" when at certain azimuths. This anomaly was probably caused by the extra torque of the wires on the platform coupled with Teflon Flow at these extreme temperatures.

Another anomaly experienced was in the Ultrviolet Spectroscopy data during the solar and stellar occultation observations. Apparently, during transmission in a given data mode, the data stream can be altered (data hit), resulting in erroneous data. To correct these errors, the data are Golay Coded. This coding allows the data hits to be corrected at the expense of cutting the data volume in half.

Prior to launch, the Principle Investigators for the Ultraviolet Spectrograph experiment decided not to have the OC-1 (the data mode used during occultation maneuvers) Golay Coded. The general consensus was to risk some data quality for a higher spatial resolution in planetary atmospheres as well as a data rate of 7.2 Kbits vs. 3.6 Kbits.

In January 1980, during a Ultraviolet Spectrograph Suncal (solar measurement), higher data counts than can be generated by the Ultraviolet Spectrograph detector or digital electronics were observed in large numbers. When the next suncal was executed in July, the data quality of OC-1 showed serious increases in deterioration. These high data counts also started appearing in GS-3, which is the Golay Coded general science mode.

However, during OC-1, the Ultraviolet Spectrograph is allocated the largest data volume with the Infrared Radiometer and Photopolarimeter as the "riding" experiments. Unfortunetly the radiometer was off and the polarimeter was non-functional. Thus any non-zero data in either the radiometer or polarimeter indicated a problem with the data. Ultra-violet Spectrograph data however,by itself, is ambiguous due to it's non-zero nature. Therefore,by comparing the number of definite high counts in radiometer and polarimeter data streams against the apparent high counts in the spectrograph data streams, one could check for consistency to determine if the anomaly was associated with the spectrograph alone or was characteristic of the data stream as a whole.

The results of the analysis indicated that the anomaly was either associated with the down link or telcom performance. Further analysis showed that the anomalous data were a function of dimensions of the radio antenna used, power of the X band and the ambient radio antenna weather conditions.

Thus the anomaly was verified as a signal strengh problem, correctable by using the high power X band and only the 64 meter or an array of the 64 meter and 34 meter radio antennas, when transmitting in the OC-1 data mode.

Fortunetly, the cruise phase is not characterized by anomalies. During this period of time, the Science Support Teams are involved with the sequencing of future loads, real time analysis and documentation of data and future trajectory selection.

Even though the Voyager spacecrafts were not intially intended to function after Saturn, Voyager II's trajectory is currently designed to take it to Uranus in January of 1986 and to Neptune in 1989.

Although all the investigations have a hand in trajectory selection, Radio Science and their Limb Tracking Maneuver will have precedents over the outcome. No other investigation has the "ability" to penetrate an atmosphere down to the surface. This ability is the result of being able to calculate the index of refraction at deeper and deeper depths as the occulted spacecraft's signal is refracted towards the earth.

From the characteristics of this signal, plus data from the Infrared Radiometer, a pressure/temperature profile can be compiled. In addition, particle structure, aerosol structure, and surface pressure can be calculated with an accuracy which is orders of magnitudes better than earth based observations.

Already the Voyager spacecrafts have broadened our knowledge of our solar system and will continue to do so for many years to come. In November of this year, Voyager I will be within 400,000 Km. of Saturn and again flood us with wealths of knowledge of our place in the solar system. This knowledge is a direct result of the many years of dedication and perseverance by the men and women who work on the Voyager Project.

Acknowledgments

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At this time I would like to thank the Planetary Geology Internship Program for this opportunity and all the people on the Voyager Science Support Teams.

ROTATION RATES OF THE B RING SPOKES AND THEIR RELATIONSHIP TO THE ROTATION RATES OF PARTICLES ACCORDING TO THE PHYSICAL LAWS OF MAGNETIC AND GRAVITATIONAL MOTION

Photographs taken by Voyager 1 during its recent encounter with Saturn revealed radial structures within the B ring. A timelapse movie made up of a series of photographs of Saturn and its rings during the approaching leg of the encounter shows these features to have a motion within the ring similar to the spokes within a wheel. These spoke-like features show a dark contrast with the ring when seen in backscattered light and a light contrast when viewed in forescattered light. This characteristic alone may be indicative of their composition. The rotation rate of the particles comprising these spokes with respect to their distance from Saturn's center may be a major clue to the controlling forces behind them.

A graph was made showing the orbital period of a particle at a certain distance from the center of Saturn as defined by Kepler's Third Law of Gravitational Motion, P^2 R^3, where P is the period in minutes and R is the distance in R_S*. the constant for the curve was foun using the orbital period of Mimas, 1367.79 min., and its orbital radius, 3.089 R_S. Another line was drawn to represent the magnetic period, 639 min., which doesn't vary with distance. The orbital periods of the spokes with respect to the distances from from the center of Saturn were then plotted on the same graph. These periods and distances were found using every third frame of the approach movie and an overlay made by computer to correspond to the inclination of the ring plane from the spacecraft. A point along the spoke was measured for distance from the center of Saturn and it was traced through as many frames as possible to calculate its orbital period.

The resulting graph (fig. 1) showed a grouping of the spoke properties, period vs. distance, around the corotation point oft the magnetic and gravitational periods. This may help to support the theory that the spokes of the B ring are somehow related to the magnetic field of Saturn. If the rest of the particles that make up the B ring are controlled by the gravitational forces of the planet, then the change in the velocity of some of the particles due to the magnetic field would cause a variation in the apperance of th ring. Smaller particles would be the ones most likely affected by magnetic forces. These small particles would also demonstrate the different contrasts when viewed in forescattered and backscattered light.

This study has shed some light on the mystery of the B ring Spokes. However, it hasn't, by any means, solved it. Further and more detailed studies are needed to completely understand this phenomenon. Hopefully, this study will point scientists in the right direction.

* R_S= Saturn Radii (60,330 km.)

Deborah L. Young; NASA Planetary Geology Intern; Jet Propulsion Lab; Pasadena,California; Oct. - Nov. 1980

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B-RING SPOKE ROTATION RATE DATA

The data for these rates was obtained using every third frame of the PIO Ring Rotation Movie made during the Far Encounter Phase of the Voyager 1 encounter with Saturn. (FDS count # 34380.36 - 34392.54; every .18 FDS # was used.)

DISTANCE FROM SATURN(R_S^*)	PERIOD (min)
1.8	668.9
1.855	592.0
1.865	609.9
1.81	648.0
1.865	617.9
1.92	648.0
1.90	635.0
1.90	622.1
1.865	609.9
1.865	602.0
1.94	638.0
1.91	638.0
1.79	628.4
1.77	632.2
1.81	610.0
1.77	617.0
1.80	622.0
1.81	636.6
AVG.	626.4
1.71	532.0
1.72	538.6
1.72	563.5
AVG.	544.7

* R_S= radius of Saturn (60,330 km.)

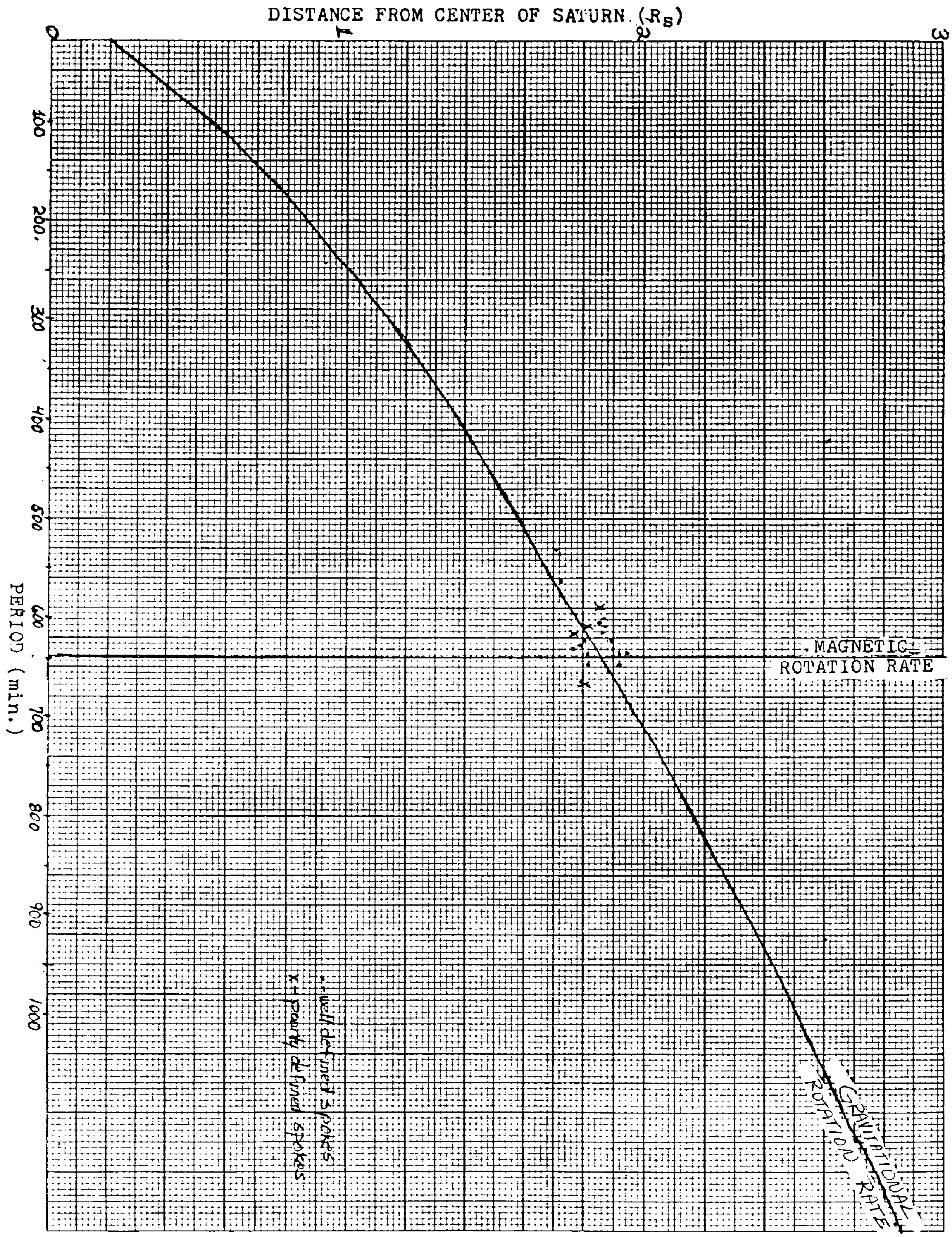
DISTANCE FROM CENTER OF SATURN (R_S)
0
1
2
3
PERIOD (min.)
100
200
300
400
500
600
700
800
900
1000
MAGNETIC
ROTATION RATE
GRAVITATIONAL
ROTATION RATE
• - well defined spokes
x - poorly defined spokes

FIG.1

SECTION III:

Regional Planetary Image Facilities--Photographic Holdings

Gail S. Georgenson

REGIONAL PLANETARY IMAGE FACILITIES -- PHOTOGRAPHIC HOLDINGS
Compiled by Gail S. Georgenson, Space Imagery Center, University of Arizona

The Regional Planetary Image Facilities (RPIFs) provide easy access to NASA's lunar and planetary imagery. The network of seven facilities enables scientists, students, educators, and the general public to select necessary image copies and carry out research within each facility. Local librarians assist users in acquiring hard copy products for permanent retention by referral to various NASA photo contractors. Cooperation among the RPIF members permits access to materials without unnecessary trips to a distant facility. In addition, three new branch libraries now allow an even greater number of interested users to access NASA photo files. Though the branch facilities do not contain the same range of NASA photo products as the regional facilities, they can assist in referrals to the regional libraries and NASA photo contractors. Complete addresses for the seven RPIF members and three branch facilities are included at the end of the photoproduct holdings list presented here. The facilities welcome inquiries from scientists and other interested individuals.

The following list is a compilation of inventory information gathered by the regional facilities. It points out the wide range of photoproducts and formats produced for NASA interplanetary missions and provides availability information for data sets at each facility. Most of the standard distribution products are available at each facility in either partial or complete sets. However, different specific strengths (i.e., special products) exist in the individual collections indicating the past research interests of the home institutions. Again, communication within the RPIF network is strong, hence providing users maximum access to all facilities. Institutional codes and a key to abbreviations used in the listing are included below.

Institutional Codes

AZ	University of Arizona / Tucson, Arizona
BR	Brown University / Providence, Rhode Island
COR	Cornell University / Ithaca, New York
FLAG	USGS Flagstaff / Flagstaff, Arizona
LPI	Lunar and Planetary Institute / Houston, Texas
JPL	Jet Propulsion Laboratory / Pasadena, California
WASH	Washington University / St. Louis, Missouri

Key to Abbreviations

EDR	Experiment Data Record
FOVLIP	First Order Viking Lander Image Processing
MTIS	Mission Test Image System
MTPS	Mission Test Photographic System
MTVS	Mission Test Video System
Negs	Negative film
Orig	Original film
(P)	Partial set
Pos	Positive film
RDR	Reduced Data Record
SCP	Strip Contact Prints
TDR	Team Data Record
Trans	Transparencies (film)

LUNAR DATA	AZ	BR	COR	FL	LPI	JPL	WASH
Ranger 7, 8, 9							
Photo Catalogs	x		x	x		x	
Prints			x	x	x		
Transparencies - Negs-35 mm	x			x		x	
Transparencies - Pos - 35 mm						x	
Surveyor 1, 3, 5, 6, 7							
Films - 16 mm	x(P)					x(P)	
JPL Mosaics - Negs				x		x	
JPL Mosaics - Prints	x(P)			x			
70-mm Photography - Negs	x			x	x		
70-mm Photography - Prints	x(P)			x		x(P)	
Support Data	x		x	x	x		
USGS Mosaics - Negs				x		x(#5 only)	
USGS Mosaics - Prints	x(P)			x		x(#5 only)	
Lunar Orbiter 1-5							
Microfiche	x	x		x	x	x	x
Negs 4 x 5				x(P)		x(P)	
Prints 20 x 24	x	x	x	x	x	x	x
Slides - Lantern	x(P)						
Slides - 35 mm	x(P)					x(P)	
Support Data	x	x	x	x		x	x
Transparencies - Negs - 20x24				x		x	
Transparencies - Pos - 20x24	x(P)						
Apollo 5-17							
Apollo 5 - 70mm Negs						x(P)	
Apollo 5 - 70 mm Orig Film						x(P)	
Apollo 6 - 70mm Negs						x(P)	
Apollo 6 - 70 mm Orig Film						x(P)	
Apollo 6 Prints					x		
Apollo 7 Negs						x(P)	
Apollo 7 Prints					x		
Apollo Support Data	x		x			x	x
Films - 16 mm	x			x	x	x	
Hasselblad Microfiche	x	x	x	x	x	x	
Hasselblad Microfilm	x	x		x			
Hasselblad Prints	x			x	x		x(P)
Hasselblad 70-mm Film Negs				x		x	
Hasselblad 70-mm Film Pos	x	x(P)	x	x	x	x	
Metric (Mapping) Enl. Prints				x(P)	x		
Metric (Mapping) Film Negs				x	x		
Metric (Mapping) Film Pos	x(P)	x(P)		x		x	
Metric (Mapping) Microfiche	x	x		x		x	x
Metric (Mapping) Microfilm	x	x		x			
Metric (Mapping) Prints	x			x	x		x
Panoramic Camera Microfiche						x	
Panoramic Camera Microfilm		x		x			x
Panoramic Camera Negs				x	x		
Panoramic Camera Pos Trans	x	x		x	x	x	
Panoramic Camera Prints	x		x	x	x		x
Rectified Pan	x(P)			x	x		

Mariner 10 (Earth Moon Sequence)	AZ	BR	COR	FL	LPI	JPL	WASH
Microfiche	x						x
Support Data	x		x	x		x	
Systematic Products (MTVS) Negs	x			x		x	x
Systematic Products (MTVS) Pos Trans	x					x	x
Systematic Products (MTVS) Prints	x			x		x	
Systematic Products (MTVS) SCP	x		x			x	

PLANETARY DATA

Mariner 4 (Mars)	AZ	BR	COR	FL	LPI	JPL	WASH
Digital Tapes							x
Negatives						x	
Support Data					x		

Mariner 6, 7 (Mars)	AZ	BR	COR	FL	LPI	JPL	WASH
Digital Tapes							x
Special Products - Negs						x(P)	
Special Products - Prints				x		x(P)	
Support Data	x		x	x			
Systematic Products - Negs						x	
Systematic Products - Prints	x		x	x	x	x	

Mariner 9 (Mars)	AZ	BR	COR	FL	LPI	JPL	WASH
Digital Tapes							x
IPL/RDR - Microfiche	x		x			x	x
IPL/RDR - Negs				x	x		x
IPL/RDR - Pos Trans				x		x(P)	
IPL/RDR - Prints			x	x		x	x
IPL/Rectified Stereographic							
JPL Mosaic Products						x	
Press Release Prints			x	x(P)		x(P)	
Support Data (incl. Microfiche)	x	x	x	x		x	x
Systematic Products(MTVS)-Microfiche	x	x	x	x	x	x	x
Systematic Products (MTVS) - Negs		x	x	x		x	
Systematic Products (MTVS) - Pos Trans			x	x		x	
Systematic Products (MTVS) - Prints	x	x	x	x	x	x	

Mariner 10 (Mercury)	AZ	BR	COR	FL	LPI	JPL	WASH
Films - 16 mm	x					x	
IPL Mosaics	x			x		x	x
IPL/RDR - Microfiche	x						x
IPL/RDR - Negs	x			x		x	x
IPL/RDR - Pos Trans	x			x		x	
IPL/RDR - Prints	x			x	x		x
IPL/RDR - SCP	x					x	x
IPL Stereo - Negs	x				x		x
IPL Stereo - Pos.Trans	x				x		
IPL Stereo - SCP	x				x		
Press Release Prints						x(P)	x(P)
Press Release Slides						x	x
Support Data (incl. Microfiche)	x	x		x		x	x
Systematic Products (MTVS)-Microfiche	x	x			x		x
Systematic Products (MTVS) - Negs	x	x		x		x	
Systematic Products (MTVS) - Pos Trans	x			x		x	
Systematic Products (MTVS) - Prints	x	x	x	x		x	x
Systematic Products (MTVS) - SCP	x		x			x	x

Mariner 10 (Venus)	AZ	BR	COR	FL	LPI	JPL	WASH
IPL Mosaics	x(P)					x	
Support Data (incl. Microfiche)	x					x	
Systematic Products (MTVS) - Negs	x			x		x	
Systematic Products (MTVS) - Pos Trans	x					x	
Systematic Products (MTVS) - Prints	x		x	x		x	
Systematic Products (MTVS) - SCP	x		x			x	
Systematic Products (MTVS)-Microfiche	x						x
Viking Orbiter 1, 2 (Mars)							
IPL/GRE Color Filter Prints	x		x	x		x	
IPL Stereo Pairs	x		x	x		x	
JPL Mosaics - 4 x 5 Negs	x		x	x	x	x	x
JPL Mosaics - 4 x 5 Prints				x			x
JPL Mosaics - 20 x 24 Prints	x	x(P)	x	x	x	x	x
Phobos/Deimos - 8 x 10 Prints			x	x			
Phobos/Deimos - Negs	x		x	x		x	
Phobos/Deimos - Pos Trans				x		x	
Phobos/Deimos - SCP	x		x	x		x	
Press Release Photos	x(P)		x			x(P)	x
Primary & Extended Mission-8x10 Prints			x	x			
Primary & Extended Mission-Microfiche	x		x	x	x	x	x
Primary & Extended Mission - Negs	x	x(P)	x	x	x	x	x
Primary & Extended Mission - Pos Trans				x		x	
Primary & Extended Mission - SCP	x	x(P)	x	x	x	x	x
Slides - 35 mm	x		x	x		x	x
Support Data (incl. Microfiche)	x		x	x		x	x
Survey Mission - Negs	x		x	x		x	
Survey Mission - Pos Trans				x		x	
Survey Mission - SCP	x		x	x		x	
USGS Color Reference Prints	x		x	x		x	x
USGS Mosaics (Mars Charts) - Prints	x	x	x	x		x	x
Viking Lander 1, 2 (Mars)							
EDR Microfiche	x		x	x	x	x	x
EDR Negs		x	x	x			
EDR Pos Trans		x					
EDR SCP	x	x	x	x			x
EDR Digital Tapes		x	x	x			
FOVLIP Negs		x(P)	x	x			x
FOVLIP Pos Trans							
FOVLIP SCP	x	x(P)		x			x
FOVLIP Slides							x
JPL Mosaics (Hi Res) - Negs		x	x	x			x
JPL Mosaics (Stereo) - Negs		x	x	x			x
JPL Mosaics (Stereo) - Prints							x
Press Release - Prints		x	x			x	x
TDR/DIFFPICS - Negs		x	x	x			x
TDR/DIFFPICS - SCP	x	x	x	x			
TDR Negs		x(P)	x	x			x
TDR Pos Trans			x	x			x
TDR SCP	x	x(P)	x	x	x(P)		x
TDR SCP (color)	x	x(P)	x	x		x	x
TDR Slides			x		x	x	x

Voyager 1, 2 (Jupiter)	AZ	BR	COR	FL	LPI	JPL	WASH
Films - 16 mm	x		x			x	
Press Release Prints	x		x	x		x	
Press Release Slides	x		x	x		x	
Systematic MTIS/MTPS - Enlargements			x				
Systematic MTIS/MTPS - Negs	x		x	x			
Systematic MTIS/MTPS - SCP	x		x(P)	x			

Voyager 1, 2 (Satellites)	AZ	BR	COR	FL	LPI	JPL	WASH
IPL Products - Prints	x	x		x			
JPL Mosaics - Large Prints	x	x	x	x			
Press Release Prints	x	x	x	x	x	x	x
Press Release Slides	x	x	x	x	x	x	x
Systematic MTIS/MTPS Enlargements	x(P)		x	x	x	x	
Systematic MTIS/MTPS Negs	x	x	x	x	x	x	x
Systematic MTIS/MTPS Pos Trans				x	x		
Systematic MTIS/MTPS SCP	x(P)	x		x	x	x	x

Regional Planetary Image Facilities

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Houston, Texas 77058
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Flagstaff, Arizona 86001
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BROWN REGIONAL PLANETARY DATA CENTER
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Providence, Rhode Island 02912
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Data Manager: John Crowley
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SPACECRAFT PLANETARY IMAGING FACILITY
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Facility Director: Joseph Veverka
Data Manager: Margaret Dermott
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PLANETARY IMAGE FACILITY
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Arizona State University
Dept. of Geology
Space Photography Laboratory
Tempe, AZ 85281
Librarian: Sondra Peacock
Facility Director: Dr. R. Greeley

Louisiana State University
Dept. of Geology
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