Asteroids, Comets, Meteors 1991, pp. 521-524
Lunar and Planetary Institute, Houston, 1992

S/21-90
-140976
N93-19234

CHEMICAL AND PHYSICAL EFFECTS IN THE BULK OF COMETARY ANALOGS

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ABSTRACT

KOSI comet simulation experiments have been designed as a macroscopic tester for the studies of physico-chemical problems inherent to comet bodies. The analog samples consist of H_2O and CO_2 ice, organic admixtures, mineral dust and carbon. It is reported on two of the fundamental changes the analogs undergo when submitted to "insolation" by artificial sunlight, i.e. the diffusion of frozen gases and subsequent crust formation and the natural isotopic fractionation.

INTRODUCTION

KOSI experiments which involve many scientific groups cover a large array of both physical and chemical studies of the evolution of a "comet-like" body exposed to photon irradiation (Grün et al. 1991). The diversity of the output foreseen by the different teams implies various choices for the material used as well as for the exposure to the "sun". This is summarized in Table 1. This paper reports on sample stratigraphy and crust formation in KOSI-5 to 7 and isotopic studies in KOSI-7. KOSI is characterized by different phases which are, a) the conditionning of the sample into the space simulator, b) the irradiation, c) the further analysing of the irradiated analog. The latter requires sampling and storage under LN_2 conditions (Roessler et al. 1990, Roessler 1991). The study of the strength of the target material takes place immediatly after the sample has been removed from the space simulator and has been placed into a large glove box cooled with LN_2. The sample profile is also visually inspected for the stratigraphy and material is taken layerwise (1 or 2 cm). This material is then analysed by different techniques (Hsiung and Roessler 1989, Roessler et al. 1992a).

RESULTS

GAS DIFFUSION AND CRUST FORMATION : The evidence for gas diffusion, both inward and outward, has been outlined by the basic visual inspection and by the more sophisticated technique of gas chromatography GC (Hsiung and Roessler 1989, 1990). The visual inspection exhibits some brilliant crystallites in the depth, which quality and number varies upon material composition. They are a proof for CO_2 recrystallization (Fig.1). The GC technique was used to follow the amount of CO_2 remaining at various depths of the analog after insolation. Figs. 2 to 4, show the stratigraphy of KOSI-5 to 7. Because of the different conditions of each of the experiments, only a few general conclusions can be drawn, a) ejection of grains (Thiel et al. 1991), b) large change in the frozen gas repartition c) formation of a crust near the surface, d) sometimes an internal crust is present. KOSI-5 and 7 are reported as high activity samples, implying important recession of the surface. This is attributed to the presence of CH_3OH in KOSI 5 and the high ratio volatiles/mineral grains in KOSI 7. The insolation conditions and the target composition largely determined the thickness and strength of the crust (for more details cf. Roessler 1991, Roessler et al. 1992a). A dry dust mantle covers the external crust. Underneath this crust are some ilots of hardened material. Then a more "virgin" material appears, anyhow depleted in "gases" (CO_2, CH_3OH). Finaly a zone of higher concentration of gases is encountered below the above mentioned one due to the inward diffusion. It is found in this zone an internal crust. In Fig.5 of KOSI-5, the temperature profile at the end of the irradiation period (Benkhoff and Spohn 1991) and the CO_2 concentration profile are plotted versus the depth of the sample. The strong correlation between the temperature drop and the CO_2 excess proves the inward diffusion of gases and their recrystallization in a kind of thermochromatography. The fact of uppr and internal crust formation is also witnessed by the test on material strength by drilling boreholes (Roessler 1991, Roessler et al. 1992a)

HEAVY ISOTOPE ENRICHMENT IN H_2O PHASE : KOSI-7 reported here was conducted with material of natural isotopic composition. The analysis was done by mass spectrometry for the heavy isotopes of water, D and ^{18}O, for details cf. (Roessler 1992b). Studies on ^{13}C in CO_2 are on their way. Figs.6 and 7 report on the isotopic abundance before and after insolation. It becomes obvious from Fig.6 that the procedure of filling the sample compartment (standard or analog) had no big effect on the isotopic ratio. It should be noted, however, a slight increase with the preparation i.e. the spraying procedure of the mineral-H_2O

suspension into LN_2, (Stöffler et al. 1991, Roessler et al. 1990). Therefore, the comparison of the status before and after insolation is significant. Fig.7 exhibits a substantial change with respect to the original abundance, but only in the region of the upper crust (Fig.8) where the effect of insolation on the isotopic ratio is fairly large. The changes for D and ^{18}O are basically equivalent . The cut in the curve is observed in the same region, roughly 20 cm from the bottom, i.e. 10 cm from the original surface. Nevertheless, it should be mentionned that the curve increase coefficient is sligthly smoother for D than for ^{18}O.

DISCUSSION

It has been shown that a cometary type material undergoes drastic structural changes due to physico-chemical reactions when submitted to a visible solar equivalent radiation. In view of future cometary explorations (e.g. ROSETTA) these structural changes have to be taken into account for the scientific payload. Also the technical part of the mission will be affected by this new facts. It is obvious that the anchoring of a vessel on a body with almost no attraction requires a good knowledge of the surface characteristics and the possible internal structure, both to be able to choose remotely where to drill and to realize the sampling. One of the main interests in KOSI is to use it as a remote witness of the solar system past. From the present results it can be concluded that the presence of a strong isotopic effect from the insolation impedes somehow isotopic studies as a good tool for the determination of the nature of the pristine material in a comet. The processing of the sample is subject to, e.g. gas and grain ejection, solidification, gas diffusion, recondensation, etc. These many effects screen the possible knowledge of what can have been the material which formed the comets. Therefore, a strong deconvolution work has to be undertaken in order to propose possible scenarios of comet evolution under such condition as photon and ion irradiation, warming by tidal effects when passing by a large object, etc.

ACKNOWLEDGEMENTS

The authors want to thank the KOSI team, in particular Dr. H. Kochan (DLR-Köln), Prof. J. Klinger (Grenoble) and Messrs P. Trimborn (Neuherberg) and G. Eich (Jülich) for experimental assistance and for scientific discussion. Part of the work was sponsored by the Schwerpunktprogram "Kleine Körper im Sonnensystem" of Deutsche Forschungsgemeinschaft DFG.

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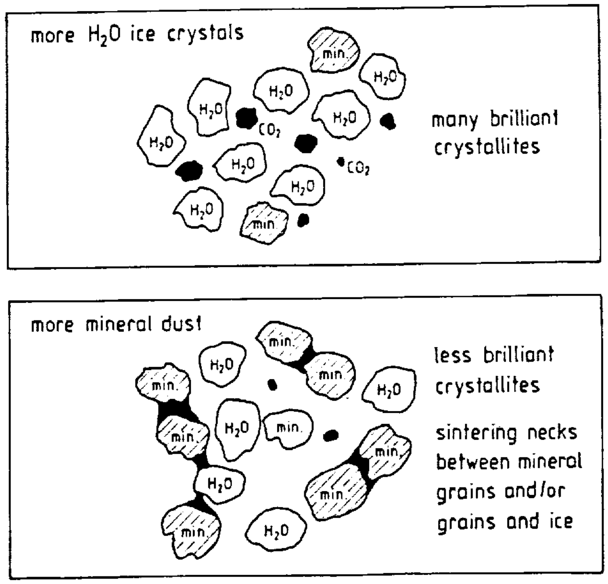


Fig.1 : Comparison of CO_2 recrystallization as a function of material composition (KOSI-6 and 7).

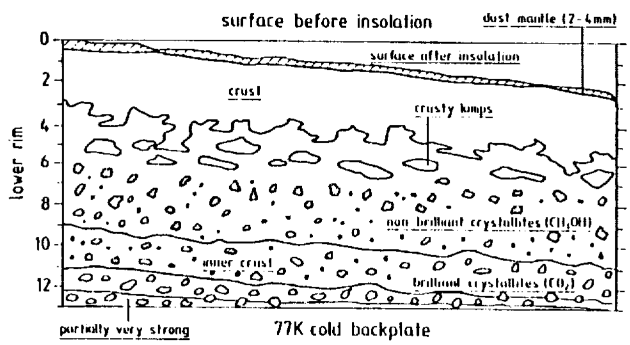


Fig.2 : Stratigraphy KOSI-5 after insolation.

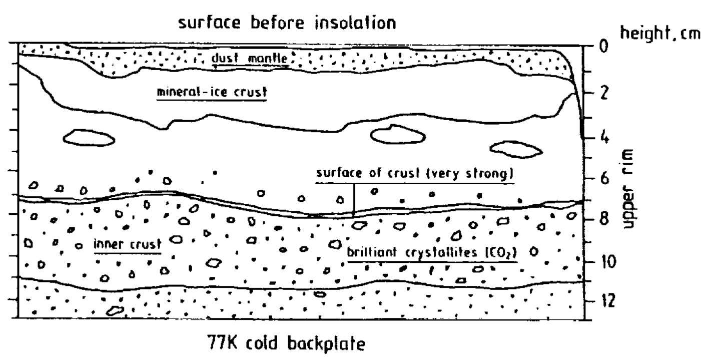


Fig.3 : Stratigraphy KOSI-6 after insolation.

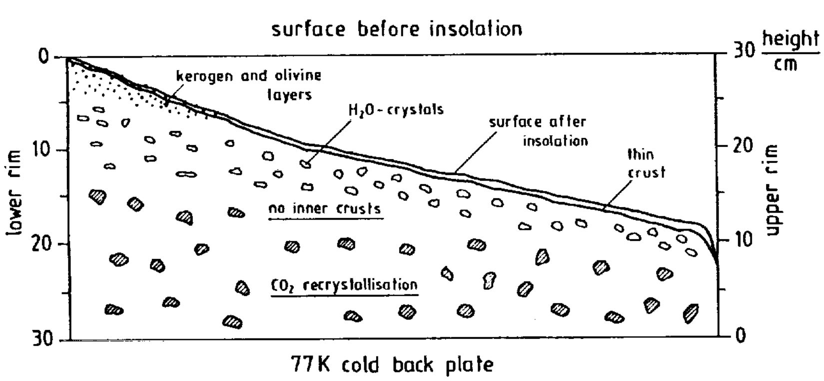


Fig.4 : Stratigraphy KOSI-7 after insolation.

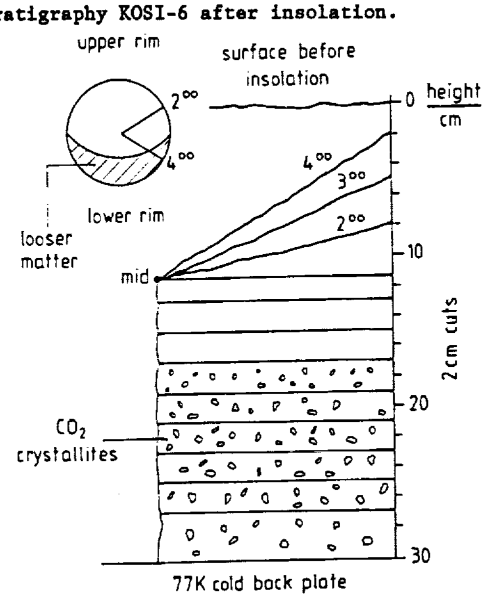


Fig. 8 : Detailed stratigraphy and sample taking geometry in KOSI-7.

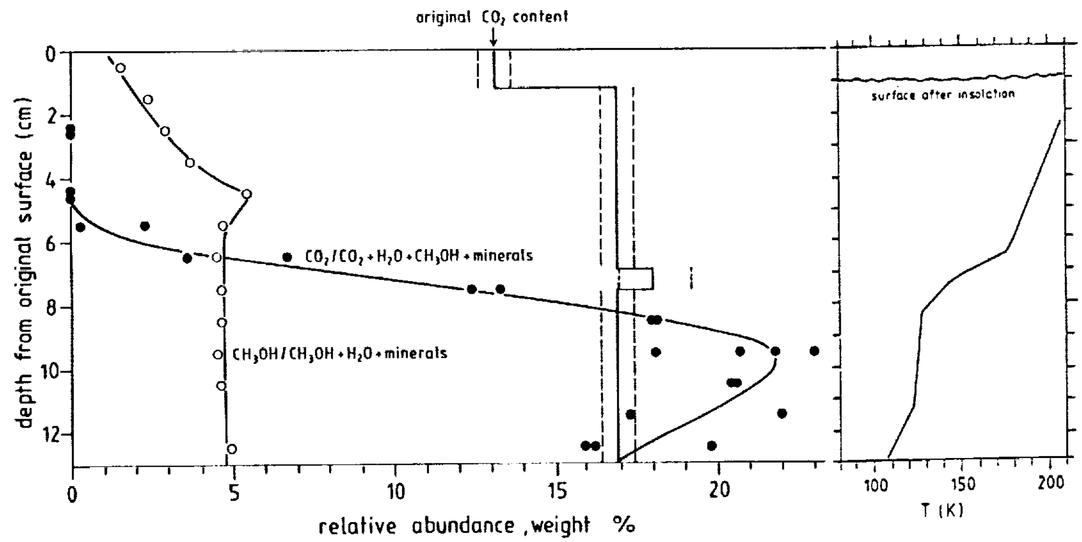
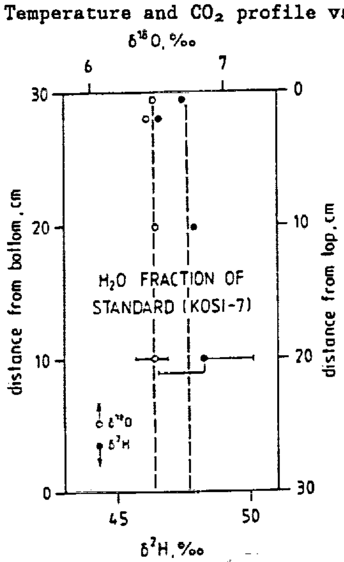


Fig. 5 : Temperature and CO_2 profile vs depth in KOSI-5, cf. Benkhoff and Spohn 1991.



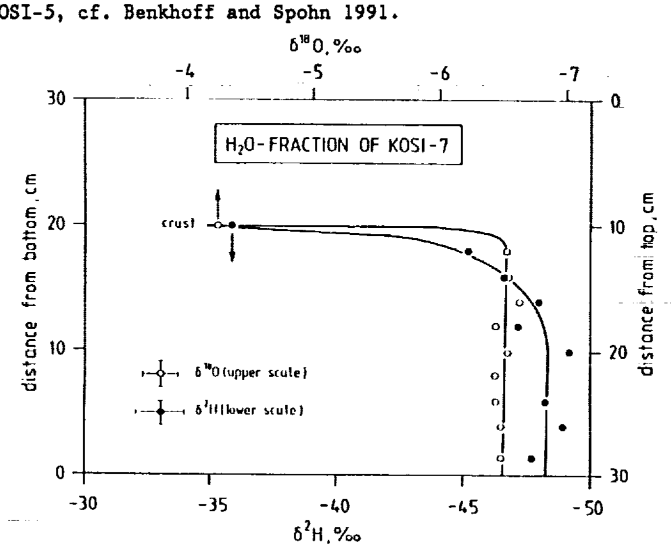


Fig.6 : Isotopic ratios in KOSI-7 before insolation. Fig. 7 : Isotopic ratios in KOSI-7 after insolation.

Table 1 : Insolation conditions and samples composition of KOSI-3 to 7

	insolation	average composition, weight % H_2O-ice	CO_2-ice	CH_3OH-ice	minerals	carbon	kerogen
KOSI-3 (Nov. 1988)	41 h 1.3 SC	78	14	–	8*	0.08	–
KOSI-4 (May 1989)	36 h 0.65 SC	77	15	–	8*	0.07	–
KOSI-5 (Nov. 1989)	12 h 1.16 SC	70	17	4	9*	0.07	–
KOSI-6 (May 1990)	24 h 1.2 SC	42	15	–	38**	5	–
KOSI-7 (Jan. 1991)	34 h 1.3 SC	83	15	–	2***	0.07	2.7 % in 2 cm surface layer

* olivine, montmorillonite 9 :1; ** 4.2 :1; *** olivine only