LITHIUM IN LUNA-24 SAMPLES

S. V. S. MURTY, P. N. SHUKLA *and* P. S. GOEL
Department of Chemistry, Indian Institute of Technology, Kanpur 208 016

(*Received 24 March 1979*)

Lithium contents for three Luna-24 samples are found to vary from 8 ppm to 10 ppm. Examination of Li values from various lunar missions show that more the KREEP content in a soil, the higher the Li value.

INTRODUCTION

Li abundances in lunar samples have been found to vary from 2 ppm to 100 ppm. However, in general, the Li values for lunar samples are higher than those of chondrites. It has been pointed out by some earlier works (Wänke *et al.*, 1977; Dreibus *et al.*, 1976, 1977) that Li does not condense with refractory elements but follows Mg, Fe silicates. Thermal volatilisation studies (Gibson & Hubbard, 1972) on lunar basalts, breccias and soil samples for alkali, alkaline and rare earth elements (REE) have shown that Li, Ba, Sr and REE do not volatilize below 1400 °C.

Several authors, in particular Wänke and co-workers (Wänke *et al.*, 1976 and earlier papers; Dreibus *et al.*, 1976, 1977) have discussed the Li abundances in detail. Earlier studies of Li in luna rsamples have been described elsewhere (Shukla & Goel, 1974; Shukla, 1977). In the present paper, the present authors describe their results on three Luna-24 samples 24123, 24148, and 24190 allotted to us.

EXPERIMENTAL

Li contents for these soils have been measured by neutron activation using the reaction Li^6 $(n, \alpha)H^3$. Details of the experimental procedure are described elsewhere (Shukla *et al.*, 1978).

RESULTS AND DISCUSSIONS

Li results for three Luna-24 soils are given in Table I. Lithium values reported for other five Luna 24 soils by Nyquist *et al.* (1977) range from 5.6 ppm to 6.2 ppm and appear to be systematically low. It can be seen that Li values do not show any depth dependence. Earlier analyses of Luna-16 and Luna-20 samples exhibited the same trend e.g., for a depth variation of 0 to 33 cm, the Li values are practically constant at about 11 ± 1 ppm (Shukla & Goel, 1974). This observation alongwith the grain size independence of Li (Shukla, 1977) and no marked enrichment or depletion of Li in soils over rocks and breccias indicate that the various regolith processes do not seem to cause any redistribution of Li.

From earlier studies in this laboratory and elsewhere (Shukla, 1977; Wänke and co-workers) it has been observed that Li shows a positive correlation (in varying

TABLE I

Li *values of Luna* 24 *samples**

Sample No.	Depth cm	Weight mg	Li ppm
24123–13	122–123	5.5	08.4
24148–11	147–148	8.0	10.0
24190–14	189–190	7.5	08.8

*Error ± 10%

TABLE II

Li *values (ppm) for various lunar mission (soil samples)*

Mission		Literature		This Laboratory	
		Range	Average	Range	Average
Apollo	11	—	11[1]	—	—
	12	15–24	18[2]	—	—
	14	19–25	23[3]	—	—
	15	8–16	11[4]	16–17 (3 soils)	17
	16	6–10	8[4]	8–10	9
	17	7–11	9[4]	9–13	11
Luna	16	—	11[5]	10–12	11
	20	—	6[6], 6[7]	7 (2 soils)	7
	24	5.6–6.2	6[8]	8–10 (3 soils)	9

1. Annell and Helz (1970). 2. Cuttitta *et al.* (1971). 3. Rose *et al.* (1972). 4. Cuttitta *et al.* (1973) and Rose *et al.* (1973, 1974, 1975). 5. Vinogradov (1973). 6. Nava and Philpotts (1973). 7. Reed and Jovanovic (1973). 8. Nyquist *et al.* (1977).

degree) with elements like Be, Na, K, U, La, Zr and Nb. Of these elements, Li correlates strongly with Be and Nb. Due to lack of trace elements data for the soils studied in this work, various elemental correlations for these soils could not be checked.

In Table II, Li values for various Apollo and Luna missions are summarized. The highest Li values are observed for Apollo–14 samples which are mostly KREEP rich. Further, it may be pointed out that in Apollo–12 sample 12013, (pointed out to represent a KREEP sample by Hubbard *et al.*, 1971) highest values for Li (~100 ppm) have been observed for some density fractions. Thus it appears that the more the KREEP component in a soil, the higher the Li value. A low value of Li for the Luna–24 soils could be taken to indicate a low KREEP component for these soils.

ACKNOWLEDGEMENTS

The authors are most grateful to the U.S.S.R. Academy of Sciences for making available to the Indian National Science Academy (INSA) samples of the valuable lunar material. Thanks are also due to Professor D. Lal, F.N.A. and Professor N. Bhandari for their efforts in sample procurement and distribution. This research was partially supported by a grant from the Department of Space, Bangalore.

REFERENCES

Annell, C. S., and Helz, W. (1970). Emission spectrographic determination of trace elements in lunar samples from Apollo-11. *Proc. Apollo-11 Lunar Sci. Conf. Geochim. Cosmochim. Acta Suppl.*, No 1, **2**, 991–994. Pergamon Press.

Cuttitta, F., Rose, H. J. Jr., Annell, C. S., Carron, M. K., Christian, R. P., Dwornik, E. J., Greenland, L. P., Helz, A. W., and Ligon, D. T. Jr. (1971). Elemental composition of some Apollo-12 lunar rocks and soils. *Proc. Second Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 2, **2**, 1217–1229. MIT Press.

Cuttitta, F., Rose, H. J. Jr., Annell, C. S., Carron, M. K., Christian, R. P., Ligon, D. T. Jr., Dwornik, E. J., Wright, T. L., and Greenland, L. P. (1973). Chemistry of twenty-one igneous rocks and soils returned by the Apollo-15 mission. *Proc. Fourth Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 4, **2**, 1081–1096. Pergamon Press.

Dreibus, G., Spettel, B., and Wanke, H. (1976). Lithium as a correlated element, its condensation behaviour, and its use to estimate the bulk composition of the moon and the eucrite parent body. *Proc. Seventh Lunar Sci. Conf. Geochim. Cosmochim, Acta Suppl.* No. 7, **3**, 3383–3396. Pergamon Press.

———(1977). Lithium and halogens in lunar samples. *Phil. Trans. R. Soc. (Lond.)*, A. **285**, 49–54.

Gibson, E. K., and Hubbard, N. J. (1972). Thermal volatilisation studies on lunar samples. *Proc. Third Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 3, **2**, 2003–2014. MIT Press.

Hubbard, N. J., Meyer, C. Jr., Gast, P. W., and Wiesmann, H, (1971). The composition and derivation of Apollo-12 soils. *Earth Planet. Sci. Lett.*, **10**, 341–350.

Nava, D. F., and Philpotts, J. A. (1973). A lunar differential model in light of new chemical data on Luna-20 and Apollo-16 soils. *Geochim. Cosmochim. Acta.*, **37**, 963–973.

Nyquist, L., Wiesmann, H., Bansal, B., Wooden, J., McKay, G., and Hubbard, N. (1977). Chemical and Sr-isotopic characteristics of the Luna-24 samples. *Conf. Luna-24*. The Luna Science Institute Houston, 139–142.

Reed, G. W., and Jovanovic, S. (1973). The halogens in Luna-16 and Luna-20 soils. *Geochim. Cosmochim. Acta*, **37**, 1007–1009.

Rose, H. J. Jr., Cuttitta, F., Annell, C. S., Carron, M. K., Christian, R. P., Dwornik, E. J., Greenland, L. P., and Ligon, D. T. Jr. (1972). Compositional data for twenty-one Fra Mauro lunar materials. *Proc. Third Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 3, **2**, 1215–1229. MIT Press.

Rose, H. J. Jr., Cuttitta, F., Berman, S., Carron, M. K., Christian, R. P., Dwornik, E. J., Greenland, L. P., and Ligon, D. T. Jr. (1973). Compositional data for twenty-two Apollo 16 samples. *Proc. Fourth Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 4, **2**, 1149–1158. Pergamon Press.

Rose, H. J. Jr., Cuttitta, F., Berman, S., Brown, F. W., Carron, M. K., Christian, R. P., Dwornik, E. J., and Greenland, L. P. (1974). Chemical composition of rocks and soils at Taurus-Littrow.. *Proc. Fifth Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 5, **2**, 1119–1133. Pergamon Press.

Rose, H. J. Jr., Baedecker, P. A., Berman, S., Christian, R. P., Dwornik, E. J., Finkelman, R. B., and Schnepfe, M. M. (1975). Chemical composition of rocks and soils returned by the Apollo-15, 16 and 17 missions. *Proc. Sixth Lunar Sci. Conf., Geochim. Cosmochim. Acta, Suppl.*, No. 6, **2**, 1363–1373. Pergamon Press.

Shukla, P. N. (1977). *Ph. D. Thesis*, IIT, Kanpur.

Shukla, P. N., and Goel, P. S. (1974). Measurement of lithium in Luna soils by neutron activation analysis in '*Further Advances in Lunar Research*' (*Ed.* : N. Bhandari & M. N. Rao). INSA New Delhi, 53–56.

Shukla, P. N., Kothari, B. K., and Goel, P. S. (1978). Simultaneous determination of nitrogen and lithium by thermal neutron activation analysis. *Anal. Chim. Acta.*, **96**, 259–269.

Vinogradov, A. P. (1973). Preliminary data on lunar soil collected by the Luna-20 unmanned spacecraft. *Geochim. Cosmochim. Acta*, **37**, 721–729.

Wänke, H., Palme, H., Kruse, H., Baddenhausen. H., Cendales, M., Dreibus, G., Hofmeister, H., Jagoutz, E., Palme, C., Spettel, B., and Thacker, R. (1976). Chemistry of lunar highland rocks : a refined evaluation of the composition of the primary matter. *Proc. Seventh Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl.*, No. 7, **2**, 3479–3499. Pergamon Press.

Wänke, H., Palme, H., Baddenhausen, H., Dreibus, G., Kruse, H., and Spettel, B. (1977). Elemental correlations and the bulk composition of the moon. *Phil. Trans. R. Soc.* (*Lond.*), **A 285**, 41–48.