Mössbauer Effect Study of Libyan Desert Silica Glass

by

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ABSTRACT

The Mössbauer effect and X-ray fluorescence techniques are applied to study the Libyan Desert Silica Glass. The X-ray flourescence proved the existence of 13 elements in each sample of five glass types with differences in their relative abundance. The Mössbauer effect spectra showed a complex two spectral lines. Computer analysis gave Mössbauer effect parameters similar to those of iron silicate minerals, but no Fe^{3+} ions are detected. It is concluded that this Libyan Desert Silica Glass is one type of tektites formed by a huge meteorite impact on the earth's surface in that area.

استخدام ظاهرة موسباور
لدراسة زجاج الصحراء الليبية السليكوني

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تناول هذا البحث نتائج دراسة على زجاج السليكا المصري الليبي الذي اكتشف في المكان الوحيد بالعالم على الحدود المصرية الليبية سنة ١٩٣٢ ، أجريناها باستخدام مطياف ظاهرة موسباور ، وومبض الاشعة السينية . وهذا الزجاج الطبيعي الذي يطلق عليه احيانا L. D. S. G. أو الزجاج السليكي بالصحراء الليبية ، يرجع عمره طبقا لبعض الابحاث الى ٣٨ مليون سنة مضت . وهدفنا في الدراسة الحاضرة هو محاولة تبيان اصل هذا الزجاج باستقصاء التركيب فوق الدقيق له اذ ان اصله لايزال موضع جدل بين العلماء . هل هو صهير فضائي (تكتايت) حقيقي من جراء اصطدام نيزك بالارض ام انه مجرد زجاج ارضي تكون على سطح الأرض ؟

ولقد اظهرت لنا الدراسة بالاشعة السينية الوميضية ان جميع انواع ذلك الزجاج التي صنفها المتحف الجيولوجي بالقاهرة سنة ١٩٦٩ الى سبعة اصناف من حيث مظهرها الخارجي ، تحتوي على نفس العناصر مع اختلافات في النسب فقط بين النوع والآخر ، كما ظهر لنا من القياسات بظاهرة موسباور ان ايونات الحديدوز الثنائية توجد في موقعين مختلفين يبينهما بارامترات موسباور المميزة لبعض معادن السليكات مثل البيروكسين والاوليفين والكمنجتو نايت والانثوفيلايت وهي المعادن التي يحتل الحديد فيها أكثر من موقع (في البللورة) والتي ظهرت بارامترات موسباور المميزة لها في ثرى (لونر) الذي احضرته بعثة ابوللو (١١) من القمر . ونزيد ايضاحا ان نتائج البحث الحالي ـ في اعتقادنا ـ تؤكد تطابق طيف موسباور لهذا الزجاج السلكي الطبيعي مع طيف موسباور لبعض الصهارات الفضائية (التكتايت) المؤكدة . مما يدفعنا الى ترجيح الرأي القائل بأن هذا الزجاج هو نوع من (التكتايت) تكون نتيجة ارتطام نيزك ضخم بسطح الارض في هذه المنطقة .

Introduction

Libyan Desert Silica Glass (L.D.S.G.) is a natural silica glass discovered [1] in 1932 by the Egyptian Geological Survey Expedition at the Western Desert of Egypt (north-east Africa, about 480 miles south-west of Cairo, lat. 25°.30, long. 25°). It was dated to about 38 million years ago and is considered by some [2-6] as a tektite, but is found in much larger pieces and in greater quantities than any tektite yet known. It showed a variety of types which were classified [7] according to their colour and appearance, as: 1– Transparent, 2– Translucent, 3– Milky, 4– Vuggy, 5– Xenolithic, 6– Bonded, and 7– Blackish. Chemical analysis [8] of this glass showed the following chemical composition:

	%
SiO_2	98.20
TiO_2	0.32
Al_2O_3	0.70
FeO	0.53
Fe_2O_3	0.24
NiO	0.02
MgO	0.01
CaO	0.30
Na_2O	0.33
K_2O	0.02
H_2O	0.06
Total =	100.64

Some attempts and studies [2, 7] were undertaken concerning its features, locality and chemical compositions. The study of the ratio $\frac{Fe^{3+}}{\text{total iron}}$ was made [9] using the electron magnetic resonance in order to identify its origin.

The origin of this glass is still unsettled, whether it is a true tektite formed by the fall of a large meteorite, or an earthy natural glass. Geigengack and Alfar [10] think that it retains significant terrestrial origin.

The aim of the present work is to apply the Mössbauer Effect and X-ray flourescence techniques for the first time to study this glass in an attempt to identify its origin.

Experimental

Samples of five types of the L.D.S.G. are obtained from the Geological Museum in Cairo and are studied using the Mössbauer Effect and X-ray fluorescence techniques. The types studied are: vuggy, milky, transparent, blackish and translucent. The Mössbauer Effect absorber is prepared from the finely powdered material in the form of a pressed disc containing 40 mg/cm^2 of the sample. The source was 30 mci ^{57}Co in chromium matrix. The measurements are carried out at room temperature and the spectra are analysed using a computer.

Results and Discussion

The results of the X-ray fluorescence analysis for the five types of L.D.S.G. mentioned above are summarized in Table 1. It can be observed that all types contain the same elements with slight differences in the abundance.

The Mössbauer Effect measurements were carried out on the blackish type only since it contains the highest percentage of iron. Fig. 1 shows the Mössbauer Effect spectrum of this glass sample. Computer analysis of this broad and asymmetric two lines spectrum demonstrates the existence of two different quadrupole split doublets arising from two different electric field gradients and indicating that there are at least two unequivalent sets of sites for the iron in this glass. Analysis of this spectrum gave the Mössbauer Effect parameters listed in Table 2.

The values of the Mössbauer Effect parameters are characteristic of Fe^{2+} ions only. The chemical analysis indicated the presence of 0.24% as Fe_2O_3 but the analysis of the Mössbauer Effect spectrum did not show the presence of any Fe^{3+} peaks.

The values of the Mössbauer Effect parameters are in agreement with those obtained for some iron-bearing silicate minerals (Table 2) such as cummingtonite, anthophyllite, pyroxene, etc. in which iron ions occupy more than one site.

Moreover, the measured Mössbauer Effect spectrum is identical with that obtained by Marzolf *et al.* [13] for some tektites. The difference in the values of the Mössbauer parameters of our measured sample and those of tektites (Table 2) can be due to the possibilities of resolving the two doublets in our case. Another reason for the difference can be the difference in the iron percentage in our sample and in the tektites measured by Marzolf *et al.*

The difference in the values of quadruple splitting and isomer shift of M_1, M_2 and M_3 group and those of M_4 doublet is because of the asymmetry in the width and height of the observed two spectral lines. This asymmetry was explained by Marzolf *et al.* in the case of tektites, to be due to the variations in the bond distances and angles from one iron atom to the next one in glass.

Conclusion

The analogy of the chemical composition of the L.D.S.G. and the tektite, together with the identity of the Mössbauer Effect spectrum, allows us to suggest that L.D.S.G. is one type of tektites which was formed by a huge meteorite impact, that fused the country rock of the site where the impact happened, and threw it into space from where it returned back to where it is found now, but this needs a great deal of field confirmation.

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TABLE 1

The X-ray fluorescence results for five L.D.S.G. samples

Sample No.	*1 Vuggy*	*2 Milky*	*3 Transparent*	*4 Blackish*	*5 Translucent*	*Errors*
Ti	850	360	720	900	320	+ 400 - 600
V	310	–	260	–	260	± 200
Cr	560	360	390	620	460	+ 150 - 200
Mn	780	520	470	390	500	+ 100 - 200
Fe	2400	2960	2500	5200	3500	± 150
Co	320	340	270	165	245	± 70
Ni	127	113	108	65	120	± 40
Cu	130	120	365	247	156	± 40
Zn	115	48	329	274	186	± 30
Pb	14	12	14	22	16	± 8
Sr	16.8	24.4	28	24.6	30.5	± 3
Zr	192	240	266	200	136	± 3
Y	35	43.5	33	39.5	27	± 6

1– Practically above Z>20 atomic number

2—The concentrations are given in ppm/10^{-4}%/

TABLE 2

The ME parameters of the L.D.S.G. and some iron-bearing silicate minerals.

Sample material	*lattice site*	*I.S. (mm/s)*	*Q.S. (mm/s)*	*Γ (mm/s)*	*I (%)*	*References*
Desert Libyan Silica Glass	M_1, M_2, M_3	1.10 ± 0.02	2.30 ± 0.07	0.59 ± 0.05	45.3%	Present work
	M_4	1.05 ± 0.02	1.56 ± 0.06	assumed to be equal for each line	54.7%	
Cummingtonite-grunerite	M_1, M_2, M_3	1.14 - 1.18	2.76 - 290		generally 50%	11
$(Fe,Mg,Mn)_7\ Si_8O_{22}(OH)_2$	M_4	1.05 - 1.11	1.50 - 1.68		generally 50%	
Anthophyllite	M_1, M_2	1.12 - 1.13	2.58 - 2.61		generally 50%	11
$(M_g,Fe)_7\ Si_8O_{22}(OH)_2$	M_4	1.09 - 1.11	1.80 - 1.81		generally 50%	
α - Fe		0	0		4.5	
Olivine $(M_g,Fe,Mn)_2SiO_4$	M_1, M_2	1.17	2.75		28.5	12
Pyroxene	M_1	1.17	2.75		59.5	
$(mg,Fe,M_2)_2\ Si_2O_6$	M_2	1.09	1.96		59.5	
Elmenite ($Fe\ Ti\ O_3$)		1.05	0.71		7.5	
Tektites		0.80 - 0.92	1.84 - 2.08	0.61 - 0.74 (for peak 1) 0.79 - 1.00 (for peak 2)		13

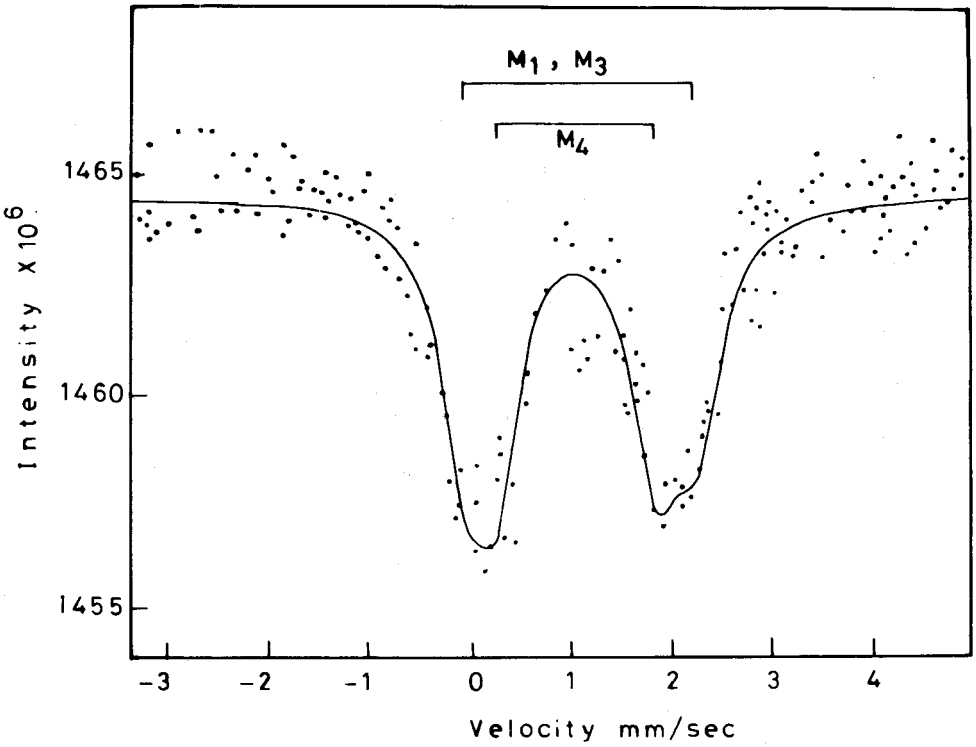

Fig. 1: Room temperature Mössbauer Effect spectrum of Libyan Desert Silica Glass Sample

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