Publ. Astron. Obs. Belgrade No. 85 (2008), 199 - 206 *Contributed paper*

THE IMPACT OF INTERNATIONAL SCIENTIFIC TEAMS ON INVESTIGATIONS OF YUGOSLAVIAN METEORITES

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Abstract. Investigations of scientific heritage is very important for every country. The evidence concerning the meteorites which have fallen upon the territory of former Yugoslavia can be a nice example. The samples of Yugoslav meteorites can be found in the biggest world museums of natural history (in Washington, Moscow, Vienna, Paris, Budapest, Berlin, Prague and London). In such a way scientists engaged in the area of meteorites, cosmochemistry, cosmic mineralogy, astrochemistry, astrophysics and other multidisciplinary scientific branches have the possibility to study these meteorites. The huge impact on the study of Yugoslav meteorites is given by international teams from Institute of Physics (Belgrade), Joint Institute for Nuclear Investigations (Dubna, Russia), Naturhistorisches Museum (Vienna, Austria), Institute of Geochemistry and Analytical Chemistry (Moscow, Russia) and Museum of Natural History (Belgrade).

1. INTRODUCTION

Investigation of scientific heritage is very important for every country. It is important to emphasize scientific and cultural identity of Serbia and other republics of former Yugoslavia. It can be seen, among other things, in investigation of meteorites falling up on the territory of former Yugoslavia (Table 1). Starting from the first discoveries of meteorites on this territory the investigations are carried out by outstanding international scientific teams.

The samples of Yugoslavian meteorites can be found (Table 2) in the biggest world museums of Natural History (in Washington, Moscow, Vienna, Paris, Budapest, Berlin, Prague and London). In such a way, scientists engaged in area of meteoritics, cosmochemistry, cosmic mineralogy, astrochemistry, astrophysics and other multidisciplinary sciences have the possibility to investigate these meteorites. The huge impact in investigations of Yugoslav meteorites is given by international teams from Institute of Physics (Belgrade), Joint Institute for Nuclear Investigations (Dubna, Russia), Naturhistorisches Museum (Vienna, Austria), Institute of Geochemistry and Analytical Chemistry (Moscow, Russia) and Museum of Natural History (Belgrade).

Table 1: Meteorites registered on the territory of former Yugoslavia

Name of meteorite, State	Date	Type Classification	Weight [kg]	Geographical latitude [N]	Geographical longitude [E]
Avce*, Slovenia	31.03.1908	IIA	1.23	46°	13°30′
Ozren, BH	1952	IAB-MG	3.9	44°24′	19°7′
Zavid*, BH	01.08.1897	L6	95	44°36′45″	18°25′5″
Dubrovnik*, Croatia	20.02.1951	L3-6	1.9	42°27′30″	18°26′30″
Hrasčina*, Croatia	26.05.1751	IID	49	46°6′	16°20′
Milena*, Croatia	26.04.1842	L6	10	46°11′	16°6′
Slavetić*, Croatia	22.05.1868	H5	1.708	45°41′	15°36′
Čačak*, Serbia	06.06.1919	Stoned	0.212	43°50′20″	20°20′
Dimitrovgrad, Serbia	1949	IIIA	100	43°2′47″	22°51′50″
Guč* (Guča), Serbia	28.09.1891	stoned	1.915	43°46′	20°14′
Jelica*, Serbia	01.12.1889	LL6	34	43°50′	20°26′30″
Soko-Banja*, Serbia	13.10.1877	LL4	80	43°40′	21°52′

Table 2: Meteorites-chondrites from Yugoslavia

No	Year and place of fall	Name	Type	Presence in world museums
1	1842 – Miljane, Croatia	Milena	Ol-Hy L6 chondrite	Austria, USA, Germany, UK, Yugoslavia
2	1868 – Pribić, Croatia	Slavetić	Ol-Br H4 Chondrite	Austria, USA, UK, India
3	1877 – Šarbanovac, Serbia	Soko-Banja	Ol-Hy LL4 amfoterite	Austria, USA, UK, France, Hungary, Yugoslavia
4	1877 – Jelica, Serbia	Jelica	Ol-Hy LL6 Amfoterite	Austria, France, Germany, USA, Russia, Hungary, Czech Republic, UK, Yugoslavia
5	1891 – Guč, Serbia	Guč	chondrite	lost
6	1897 – Zvornik, BH	Zavid	Ol-Hy L6 Chondrite	Austria, France, USA, UK, Czech Republic, Hungary, Yugoslavia
7	1919 – Čačak, Serbia	Čačak	chondrite	stolen
8	1951 – Molunat, Croatia	Dubrovnik	Ol-Hy L3-6 Chondrite	Austria, UK, Yugoslavia

2. COLLABORATION BETWEEN RUSSIAN AND YUGOSLAVIAN SCIENTISTS 1970-1980

Institute of Geochemistry and Analytical Chemistry:
- Team from Committee of Meteorites, Moscow
  Chief of the Committee:
  Academician Aleksandar Pavlovič Vinogradov, vice president AS USSR,
  Leonid Krinov, Aleksandar Yavnel', Larisa Kolomejceva-Jovanović,
- Team from Lab. of Cosmochemistry, Scientific Center, Chernogolovka (USSR)
  Avgusta Konstantinovna Lavrukhina

Museum of Natural History, Belgrade
  Aleksandar Kostić

3. COLLABORATION BETWEEN YUGOSLAVIAN, RUSSIAN, FRENCH AND MONGOLIAN SCIENTISTS 1980-1989

Members of team from Institute of Physics, Belgrade:
  Director of Institute of Physics prof. Radovan Antanasijević,
  Ž. Todorović, B. Jakupi

Joint Institute for Nuclear Investigations (Dubna, USSR),
  Chief of Lab. Vladimir Pavlovič Perelygin,
  S.G. Stetsenko, O. Otgonsuren, A.P. Sharma, J.S. Yadav

Museum of Natural History, Belgrade
  Aleksandar Kostić, Larisa Kolomejceva-Jovanović

4. COLLABORATION BETWEEN AUSTRIAN, RUSSIAN AND YUGOSLAVIAN SCIENTISTS 1982-1992

Team from Naturchistorishes Museum, Wien:
  Chief of Petrologic-Mineralogical Department prof. Gero Kurat,
  Franz Brandstaetter, Larisa Kolomejceva-Jovanović

Museum of Natural History, Belgrade:
  Aleksandar Kostić

5. EXPERIMENTAL RESULTS

Olivines, pyroxenes, spinels, plagioclases, siderite phase and other phases of chondrites from ex Yugoslavia – Jelica LL6, Dubrovnik L 3-6, Milena L 6, Zavid L 6, Soko-Banja LL 4 and Slavetić H4 - have been analyzed with an ARL-SEMQ electron microprobe. Average compositions of coexisting minerals from these Yugoslavian meteorites and some other chondrites were used to calculate closing temperatures for a variety of subsolidus ionic exchange reactions by applying different mineralogical thermometers.

For the meteorites Zavid and Milena, which belong to the same petrological type L6, a great similarity in the composition of silicate minerals and spinels has been determined.

The meteorite Dubrovnik is a complex breccia and it can be classified as a petrologic type L 3-6. It was originally classified (Meteorite Catalogue, Hey, 1966) as olivine-hyperstene chondrite of group L.

Based on a large number of microprobe analyses of coexisting olivines, spinels and ortho- and clinopyroxenes of the fragments from the Jelica, Milena, Zavid, Soko-Banja, Slavetić and Dubrovnik chondrite, calculations of closing temperatures of sub-solidus ion-exchange reactions using various mineralogical thermometers have been carried out.

A comparative study of the conditions of formation of Milena, Zavid chondrites and fragments from L6 part of Dubrovnik chondrite shows a good agreement with other chondrites from L group (Table 3)

Table 3: Comparison of closing temperatures of ionic exchange in minerals of chodrites group L

Meteorite	Ol-Sp (Roeder)	Ol-Sp (Fabries)	En (Mercier)	Opx-Cpx (Ishii)	Opx-Cpx (Lindsley)
Dubrovnik L3-6	480-670[+]	685-830[+]	1030-1150[+]		
Mezö-Madaras L3-6	500-750[1]				
Milena L6	475-485[+]	660-670[+]	1020-1045[+]		
Zavid L6	490-520[+]	640-700[+]	950-1050[+]		
Modoc L6	465-480[+]	650-670[+]		950- 990[2]	
Bruderheim L6				950-1000[2]	900[3]
Mocs L6				940[2]	820[3]
Colby L6				890-975[2]	810[3]
Langhalsen L6				950-970[2]	900[3]
Kyushu L6				980-1000[2]	900[3]
Bath Furnace L6				985-1025[2]	890[3]

[1] Hoinkes, Kurat (1974) [3] Olsen, Bunch (1984)
[2] Ishii, Takeda, Yanai (1979) [+]Author's results

For meteorites of H group we have obtained very good agreement of closing temperatures inside of the same petrologic type (Table 4).

Table 4. Comparison of closing temperatures of ionic exchange in minerals of chodrites group H

Meteorite	Ol-Sp (Roeder)	Ol-Sp (Fabries)	En (Mercier)
Slavetić H4+	485-500	700-720	
Allegan H6+	440-460	625-640	
Beddgelert H5*		740-790	
Forest Yale H4*		770-810	
Sharps H3*		800-950	
Tieschitz H3*		780-1000	
Pontlyfni H6+			1070
Mount Morris H6+			1075
Kakangari H3+			1180

* Wlotzka (1985), +Author's results

Comparison of closing temperatures of Soko-Banja LL4 chondrite and Jelica LL6 chondrite with those of other equilibrated and almost equilibrated chondrites shows a good agreement (Table 5).

Table 5. Comparison of closing temperatures of ionic exchange in minerals of chodrites group LL

Meteorite	Ol-Sp (Roeder)	Ol-Sp (Fabries)	En (Mercier)
Soko-Banja LL4+	475-510	670-700	970-1060
St. Mesmin LL4+			980-1050
Jelica LL6+	480-515	680-710	1035-1060
Siena LL6+	490-515	680-695	1050-1100
Lake Labyrinth LL6*			960- 975
Dhurmsala LL6*			975-1005
Naš LL6*			945- 955
Ottawa LL6*			995-1010
Manbhoom LL6*			965- 970
Ensisheim LL6*			965-1005

* Ishii et. al. (1979), +Author's results

The track density depends on cooling rates and closing temperatures of chondrites because ionic diffusion through minerals is controlled by the cooling rate.

The particle tracks and Ni-Fe metal-based methods suggested cooling rates between 1 and 100°C per million years for most of ordinary chondrites. Comparison of these data with our results shows a good agreement. Slower cooling rates (about 6-8 times) for equilibrated chondrites allowed more time for ionic redistribution in the crystal structure.

The fission tracks are very sensitive to thermal metamorphism. Heating over a million years is enough to anneal the existing fission tracks in minerals.

6. CONCLUSIONS

The comparison of conditions during thermal metamorphism of Yugoslavian chondrites and some other meteorites shows a very good agreement of the closing temperatures for minerals from recrystallized fragments. Study of the thermal history of Yugoslavian chondrites shows a very strong influence of thermal metamorphism on the mineralogy and phase composition of these meteorites.

All Yugoslavian chondrites can be divided into two groups:

1 group – equilibrated chondrites (Zavid, Jelica, Milena). The process of slow cooling (annealing) results in small track density. This group is not perspective for fossil tracks investigations.

2 group – unequilibrated chondrites (Dubrovnik, Slavetić, Soko-Banja). Uneqilibrated chondrites have been generated during process quenching (fast cooling). The retention of fission tracks is much better than in the first group.

The lower cooling rates of metamorphosed "equilibrated" chondrites (6-7 petrologic types) indicate that the depths of metamorphism processes inside of parent bodies were different for "equilibrated" and "unequilibrated" chondrites.

The processes of metamorphism in the terrestrial lithosphere and chondrite parent bodies, besides manifold differences, have many similarities.

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