A NOTE ON CHROME SPINELS AND ORE MINERALS FROM THE KÜRE AREA, NORTHERN TURKEY

Musa **GÜNER**

Department of Geology, University of Lund, Sweden

The Küre area is situated 20 km from the Black Sea coast in the western part of the Pontides. Its geology, the massive sulfide deposits and the paleomagnetism are treated in special publications (Güner, in press). The present paper reports work done on chrome spinels and ore minerals from the Küre rocks. Spinels, in which chromium is a major component, occur in peridotite, serpentinite, and metasomatites. Geologically, they play an important part as a connecting link between the Küre basaltoids and their alteration products (Güner, in press). In the course of study, microprobe analyses, reflectivity measurements and determinations of the Vickers hardnesses of the chrome spinels were made. Reflectivities and Vickers hardnesses were also determined for the different sulfide minerals of the massive ores and the oxide phases of the disseminated ores and basaltoids.

The microprobe chemical analyses of chrome spinels were made by a Cambridge Scientific Instruments «Geoscan Mk II». For the measurements of reflectivity the writer used a Leitz Microscope Photometer MPW mounted on an Ortholux-Pol polarizing microscope connected to a light-measuring device (type BN 5002 T) with a high-stability current supply (type NSHM). A solid filter of 546 nanometres wavelength, was also employed. The reflectivity standard was a SiC (R=20 %) crystal,, polished and calibrated by Carl Zeiss Company. The Vickers microindentation hardness was determined using a Leitz DURIMET Small-Hardness Tester. Loads of 25, 50, 100, and 200 grams at indenting periods of 15 to 20 seconds were employed.

Chrome spinels

To describe briefly the occurrence of the chrome spinels in different rock types the following code is used for the sake of simplicity: Spinel A = peridotite spinel, spinel B = serpentinite spinel, and spinel C = metasomatite spinel.

The sizes of the individual spinel grains commonly vary between ca 0.5 and 2.5 mm. Their macrocolors are dusky red, the colors under the microscope being as follows:

	In thin-section	*In reflected light*
Spinel A	black	light gray to pinkish gray
Spinel B	black to brown	light bluish to light gray
Spinel C	black to brown	light bluish to light gray

The grains of spinel A are euhedral to subhedral and exhibit some zoning. They are often rimmed by magnetite. Ilmenite forms exsolulion intergrowths. Inclusions of silicate minerals are rare and mostly comprise olivine and hornblende. Spinel B is more or less altered to and intergrown with serpentine, the intermineral borders being rather irregular. Serpentinization commonly results in marked corrosion. In spinel B, magnetite occurs as crack fillings and rims around the larger anhedral grains. Spinel C is characterized by numero Wintergrown, small patches of silicate minerals, chiefly chlorite or uralite. Its grains are rounded, euhedral or subhedral. This spinel is often rimmed by magnetite and hematite. In essence, spinel B is similar to spinel C„ the differences being a function of the type and degree of alteration of the ultrabasic rock that is the parent of the metasomatites..

The results of the microprobe analyses are shown in Table 1. This table demonstrates substantial compositional variation between the different grains of spinel A. The compositional specifics of this spinel type include relatively high contents of Ti and total Fe. In contrast, the contents of Cr are substantially lower than those in spinels B and C.

Table 1 - Chemical microprobe analyses (weight percent) of Küre chrome spinels

Element	*Element (%)*	*Oxide (%)*	*Element (%)*	*Oxide (%)*	*Element (%)*	*Oxide (%)*	*Element (%)*	*Oxide (%)*
	Spinel A1		**Spinel A2**		**Spinel A3**		**Spinel A4**	
Mg	4.22	7.00	4.64	7.69	4.38	7.27	5.19	8.60
Al	6.35	11.99	6.13	11.58	6.00	11.33	9.29	17.57
Si	0.11	0.23	—	—	0.10	0.22	0.10	0.21
Ti	2.29	3.82	2.47	4.12	2.59	4.33	0.83	1.38
Cr	24.69	36.08	25.19	36.82	24.65	36.03	23.80	34.78
Mn	0.47	0.60	0.35	0.46	0.40	0.52	0.34	0.44
Fe	29.79	38.33	28.75	36.98	29.06	37.38	26.76	34.43
Total	67.91	98.06	67.52	97.63	67.18	97.07	66.31	97.40
Mg/(Mg+Fe)	24.55		27.03		25.73		30.80	
	Spinel A5		**Spinel A6**		**Spinel A7**		**Spinel A8**	
Mg	5.43	8.99	3.69	6.13	3.76	6.23	3.84	6.36
Al	9.68	18.29	6.64	12.54	5.71	10.79	6.49	12.26
Si	0.08	0.17	0.10	0.21	0.08	0.17	0.79	1.69
Ti	0.76	1.27	1.57	2.63	2.44	4.07	1.81	3.02
Cr	24.62	35.98	21.51	31.44	20.76	30.34	20.36	29.75
Mn	0.37	0.47	0.44	0.57	0.31	0.40	0.31	0.40
Fe	25.19	32.41	33.49	43.08	35.39	45.53	31.21	40.15
Total	66.21	97.70	67.45	96.60	68.45	97.54	64.79	93.62
Mg/(Mg+Fe)	33.09		20.21		19.61		22.01	
	Spinel A9		**Spinel A10**		**Spinel B1**		**Spinel B2**	
Mg	6.10	10.11	6.02	9.98	8.61	14.27	8.78	14.55
Al	8.70	16.44	8.72	16.48	12.13	22.93	12.20	23.06
Si	0.20	0.42	1.37	2.93	0.09	0.18	—	—
Ti	0.28	0.47	0.35	0.58	—	—	—	—
Cr	32.13	46.96	31.12	45.48	32.27	47.31	32.67	47.74
Mn	0.39	0.50	0.47	0.61	0.42	0.54	0.38	0.49
Fe	18.65	23.99	17.60	22.64	12.30	15.82	12.10	15.57
Total	66.44	98.89	65.71	98.79	65.92	101.06	66.12	101.40
Mg/(Mg+Fe)	42.88		43.99		61.64		62.48	
	Spinel B3		**Spinel C1**		**Spinel C2**		**Spinel C3**	
Mg	7.75	12.85	9.14	15.15	9.33	15.47	9.26	15.35
Al	12.03	22.73	7.06	13.34	7.86	14.85	7.83	14.79
Si	0.08	0.17	0.17	0.36	0.09	0.18	0.08	0.17
Ti	—	—	—	—	0.07	0.12	0.07	0.12
Cr	31.82	46.56	38.94	56.92	38.02	55.57	38.20	55.83
Mn	0.43	0.56	0.76	0.99	0.60	0.77	0.49	0.63
Fe	14.03	18.05	11.23	14.45	10.90	14.03	10.79	13.88
Total	66.17	100.91	67.30	101.19	66.87	100.99	66.71	100.77
Mg/(Mg+Fe)	55.92		65.13		66.28		66.33	

Note: All iron as FeO.

Figure 1 shows that Mg and Cr show a markedly antithetic behaviour versus Fe, whilst no such relationship exists between Al_2O_3 and Cr_2O_3.

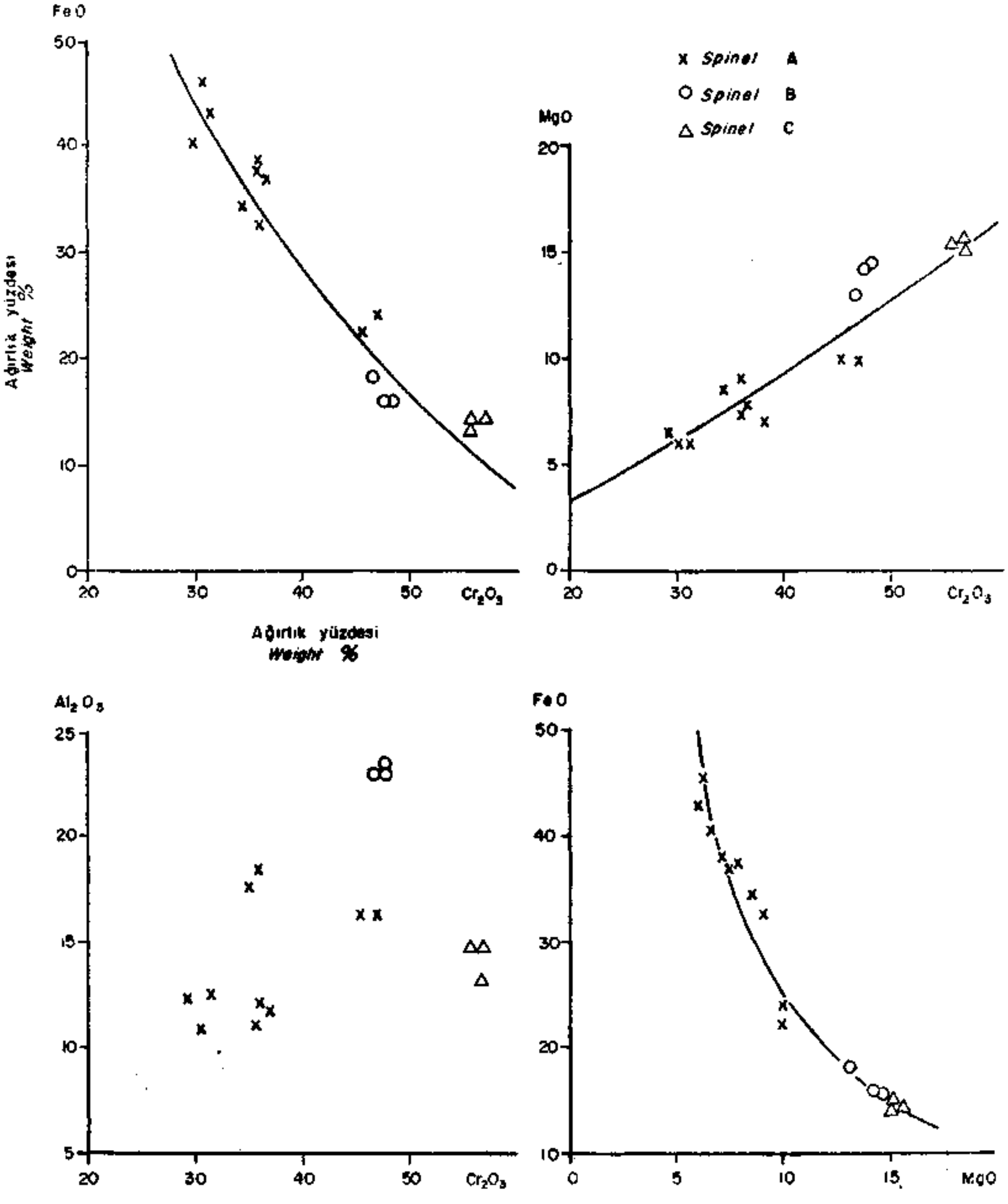


Fig. 1 - Variations of FeO, MgO and Al_2O_3 versus Cr_2O_3 and FeO versus MgO in chrome spinels from Küre. All iron as FeO.

The noticeable variations of reflectivity and Vickers hardness of the chrome spinels (Table 2) are probably due to differences in chemical composition between the individual grains, which is substantiated by the fact that the greatest variations are found in spinel A which is also chemically the most variable. In contrast, the variations in hardness are not very much larger in spinels of type A than in types B and C (1050-1480, versus 1250-1530 and 1190-1560, respectively). In general, reflectivity increases and hardness decreases with increasing contents of Fe and Ti and simultaneously decreasing Cr and Mg.

Table 2 - Reflectivities and Vickers micro-indentation hardnesses of Küre chrome spinels

	Reflectance in % (wavelength of 546 nanometres)			*Vickers micro-indentation hardness (in kg/mm²)*		
Mineral	*Number of measurements*	*Range*	*Average*	*Number of indentations*	*Range*	*Average*
Spinel A	72	12.85-15.12	13.89	62	1048-1478	1227
Spinel B	26	10.78-11.28	11.06	27	1254-1533	1388
Spinel C	36	11.80-13.86	12.57	53	1187-1561	1381

Table 3 - X ray powder diffraction data of the chrome spinels

	Spinel A[1]		*Spinel B*[2]		*Spinel C*[3]	
hkl	*dA°*	*I*	*dA°*	*I*	*dA°*	*I*
111	4.80	15	4.78	25	4.79	20
022	2.94	35	2.92	25	2.93	25
133	2.51	100	2.49	100	2.50	100
004	2.08	25	2.07	45	2.07	35
224	1.70	5	1.69	5	1.69	10
115,333	1.60	30	1.59	40	1.60	30
044	1.47	40	1.46	40	1.47	40

[1] Spinel A from peridotite.
[2] Spinel B from serpentinite.
[3] Spinel C from low-temperature metasomatite.

Ore minerals

The determinations of reflectivity and Vickers micro-indentation hardness for the sulfide minerals and the oxides are summarized in Table 4. The obtained values are compared with values given by Uytenbogaardt and Burke (1973).

Table 4 - Reflectivity and Vickers micro-indentation hardness for sulfide minerals and oxides from Küre

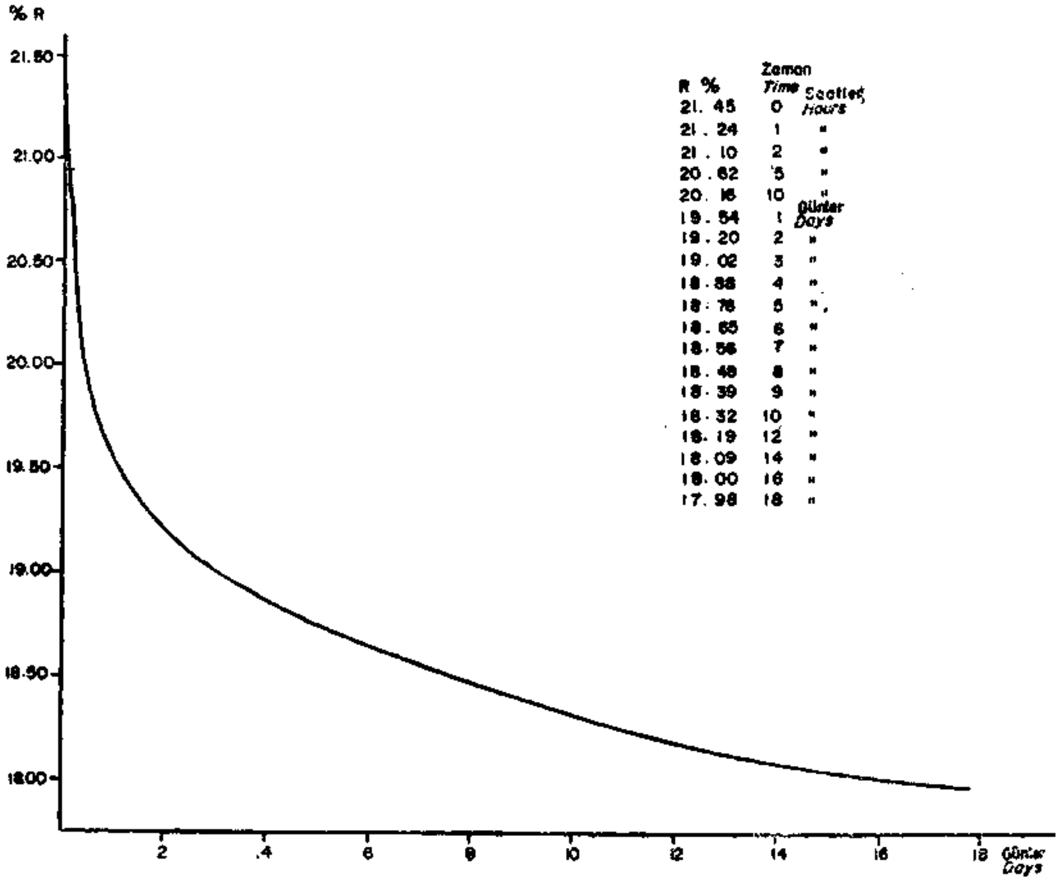
	Reflectance in % (wavelength of 546 nanometres)			Vickers micro-indentation hardness (in kg/mm²)		
Mineral	*Number of measurements*	*Range*	*Average*	*Number of indentations*	*Range*	*Average*
Pyrite	82	50.37-51.82	51.13	—	—	—
Chalcopyrite	84	44.89-47.79	46.38	26	187-216	204
Bornite	14	19.50-21.45	20.42	28	80.5-111	96.5
Covellite	10	7.00-23.00	—	20	70.5-123	98.0
Sphalerite	20	16.36-16.74	16.50	28	168-247	216
Digenite	24	19.69-20.13	19.95	44	97.6-160	122
Tennantite	18	28.57-29.68	29.00	32	351-480	385
Carrollite	14	40.00-41.19	40.68	48	370-642	518
Galena	14	41.10-41.74	41.44	26	65.5-94.0	74.7
Idaite	38	20.46-25.00	22.12	6	258-315	286
Magnetite[1]	12	20.36-20.50	20.44	30	459-560	494
Ilmenite[2]	18	15.38-18.79	17.43	—	—	—
Titanite[3]	22	9.65-12.00	10.67	30	810-1049	914
Limonite, colloform	30	11.51-13.36	12.37	14	391-464	420
ibid semicolloform	10	18.70-20.50	19.44	12	275-493	318

[1] From disseminated ores.

[2] From peridotite and basaltic rock.

[3] From basaltic rock and amphibolitized diabase.

Indentation trials on polished pyrite grains were not successful due to the cracking of the grains even at light loads. The reflectance of .pyrite, ranging from about 50.4 to 51.8 % is generally lower than the average stated in the literature. This may be due to the presence of impurities (Co?). The reflectance for sphalerite ranges from ca 16.4 to 16.7 % and is thus strikingly lower than usual, which is due to Fe-substitution (Uytenbogaardt and Burke, 1973). The hardness of carrollite varies strongly. Anhedral carrollite masses filling interstices in brecciated pyrites are much softer than euhedral grains. Neither the Vickers hardness nor the reflectance of digenite is quite in accordance with literature data. Compared with the value tabulated by Uytenbogaardt and Burke (1973), the Vickers hardness is much higher, the reflectance being distinctly lower. Impurities or compositional differences may be an explanation, but as* far as reflectivity is concerned there is a marked dependence on the length of time passing between final polishing and measurement. This aspect is illustrated particularly well by bornite, where reflectivity varies from about 19.5 to 21.5 % as a function of time (Fig. 2). The time effect is due to the gradual oxidation of the polished mineral surface, a relative stabilization of the reflectance occurring after approximately 3 days in the case of bornite. In these determinations of reflectivity, an average of four measurements were made



R %	Zaman Time	
21.45	0	Saatler Hours
21.24	1	"
21.10	2	"
20.62	5	"
20.16	10	"
19.54	1	Günler Days
19.20	2	"
19.02	3	"
18.88	4	"
18.78	5	"
18.65	6	"
18.56	7	"
18.48	8	"
18.39	9	"
18.32	10	"
18.19	12	"
18.09	14	"
18.00	16	"
17.98	18	"

Fig. 2 - The decrease of the reflectance of bornite as a function of the time lapse between final polishing and measurement.

per mineral grain. Care was taken to measure the same parts of the grain. The determinations of Vickers hardness and reflectivity for magnetite yielded fairly stable values ranging from about 460 to 560 and from about 20.4 to 20.5 % respectively.

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