A STUDY OF BAKERITE

Orhan BAYSAL

Hacettepe University, Department of Earth Sciences, Ankara

and

Erhan DİLEKÖZ

Turkish Petroleum Corporation, Ankara

SUMMARY. — *Bakerite,* a Ca-B-silicate, was encountered in the cores from the drillings on the Gölcük Plateau, in Sivas, Turkey. The mineral occurs in diabase spilite very locally as thin veins. The samples of the mineral were studied by microscopic, X-ray diffraction, chemical and differential thermal analysis methods.

The optical and X-ray diffraction properties of *bakerite* greatly resemble those of *datolite* and *herderite,* therefore comparison of bakerite with dacolite and herderite was made. In addition, the fact that bakerite is formulated in the literature in different forms, was taken into consideration and its formula was calculated from the chemical analyses and found to be $Ca_8B_{10}Si_6O_{35}6H_2O$.

INTRODUCTION

Bakerite is a basic Ca-B-silicate and it was reported from California and especially from Inyo, San Bernardino and Los Angeles by Giles (1903); Kramer and Allen (1956); Murdoch (1962).

The sample under study was found in the cores of Etibank's drillings on the Gölcük Plateau, 15 km from Şerefiye, Zara County, Sivas (Dileköz & Çağatay, 1973). These drillings are a part of a copper exploration project and are still in operation. The main rock type cut by the drillings, in this area, is partly chloritized, epidotized, and silicified diabase spilite. It is thought to have formed by the Na-metasomatism of diabase and it contains little chalcopyrite, bornite, galena and pyrite. Microlaths and microphenocrysts of plagioclase are albitized and show intersertal texture. Bakerite occurs in diabase spilite sporadically as 1-5 mm thick veins.

The literature about bakerite is somewhat incomplete and controversial. This is probably because bakerite forms very fine-grained aggregates, and is rare, but also because it greatly resembles optically and structurally datolite and herderite. It is not surprising that some researchers were unable to measure the refractive index n_y and the 2V, due to the extreme fine grain size of the mineral (Giles, 1903; Kramer & Allen, 1956); on the other hand some others calculated its formula differently (Palache *et al.,* 1951). The fact that there is a great similarity between the X-ray diffraction data and the optical properties of bakerite, datolite and herderite makes it more difficult to distinguish these minerals. For all these reasons the bakerite samples from Gölcük Plateau of Şerefiye County were studied by petrographic, X-ray diffraction, chemical and differential thermal analysis methods. The chemical formula of bakerite was calculated, criticized and was compared with the chemical formulae of similar minerals.

MICROSCOPIC STUDY

Bakerite is monoclinic; its single crystal X-ray diffraction analysis was made by Murdoch (1962). His crystallographic data is given in Table 1.

Table - 1

Crystallographic data of bakerite

Crystal system: Monoclinic			*Space group: $P2_1/c$*			
$a_0:b_0:c_0$ = 0.6342:1:1.2632			β=90°12′			
Face	Φ	p	Φ_2	p_2=B	C	A
(001)	90°00′	0°12′	89°48′	90°00′	—	89°48′
(110)	57°37′	90°00′	0°00′	- 57°37′	89°59′	32°23′
$(\bar{1}11)$	—57°33′	66°59′	153°17′	60°24′	67°09′	140°57′
(012)	0°19′	32°16′	89°48′	57°32′	32°09′	89°50′

Bakerite veins in the diabase spilites of Gölcük Plateau are composed of white massive crystal aggregates. The crystals have a stubby prismatic and platy habit and they are 0.1 to 1.5 mm in size. Platy crystals are generally big and between them are smaller prismatic crystals. Bakerite crystals are xenomorph to hypidiomorph and they do not show well-formed faces. Murdoch (1962) thinks that the most important faces of a bakerite crystal are (001), (111), (012) and to some extent (110), but, due to the poor quality of the faces it was impossible to recognize these faces.

Bakerite under the microscope is colorless, transparent and biaxial negative. Its optical properties were checked and its refractive index was measured by the oil immersion methods. The results of the optical examination, the X-ray diffraction data, together with the crystallographic data of Murdoch (1962) indicate that there is a close similarity between bakerite, datolite and herderite. Table 2 lists the optical and crystallographic data of bakerite and the data from the literature for datolite and herderite, and it is given here for comparison. Our optical data is in agreement with the data of Kramer and Allen (1956) and Murdoch (1962).

X-RAY DIFFRACTION ANALYSIS

X-ray powder diffraction analysis of bakerite was done using CuK_a radiation and Ni-filter.

Diffraction pattern and the calculated d-values are given in Figure 1 and Table 3, respectively. The d-values for the analyzed bakerite are very close to those of Kramer and Allen (1956) and Murdoch (1,962). As mentioned above, there is a close structural relationship between bakerite, datolite and herderite crystals. To show this relationship the X-ray diffraction data for these three minerals is given in Table 3. It is seen from the table that both the intensity and the location of the peaks for these minerals are vety similar and it is very difficult, if not impossible, to differentiate these minerals by their diffraction patterns. One must, therefore, make use of the slight variations in their optical properties and of quantitative chemical analyses.

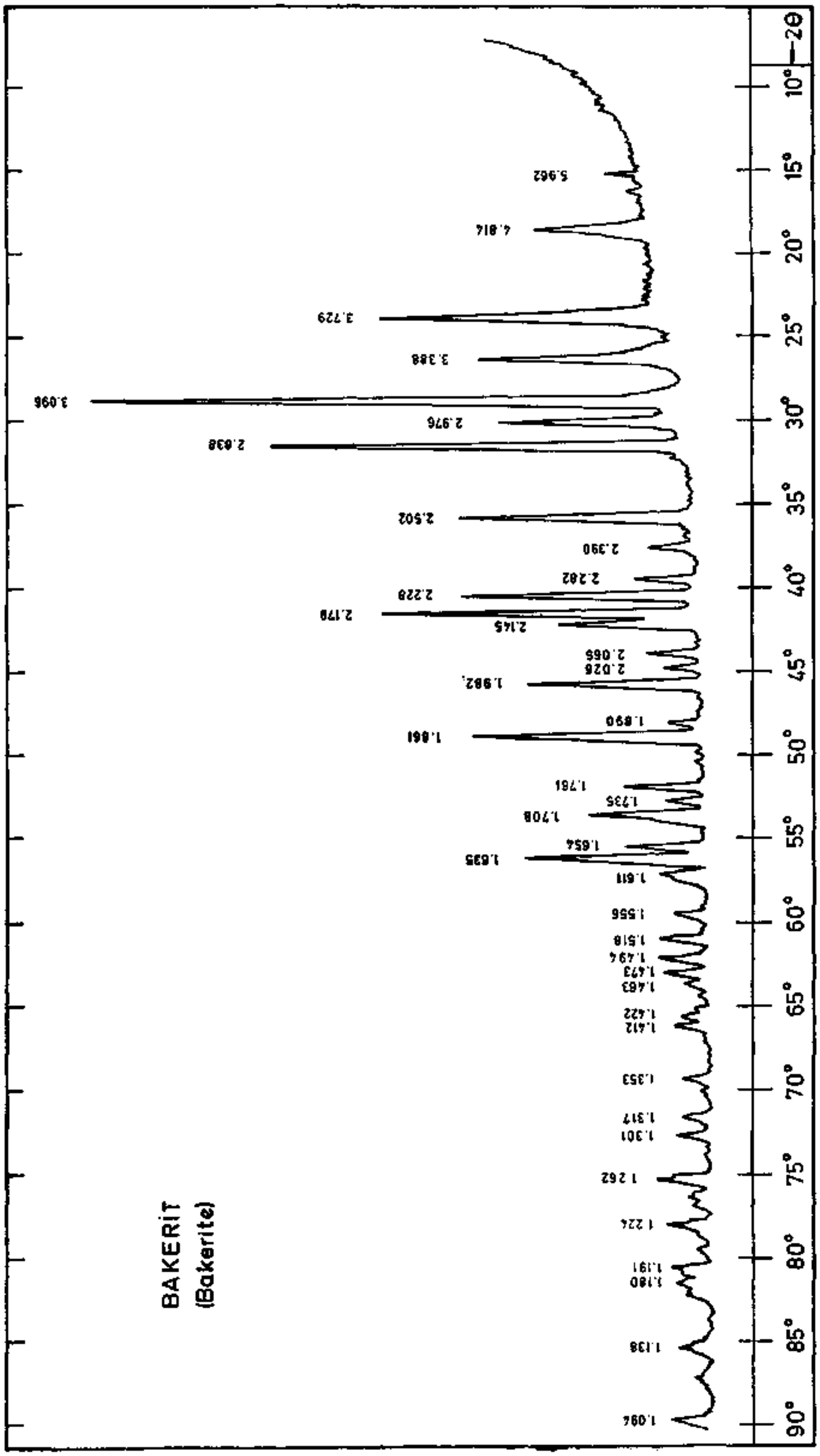

Fig. 1 - X-ray diffraction diagram of bakerite (Rad.: CuKα, Filter: nickel).

Table - 2

Crystallographic and optical properties of bakerite, datolite and herderite crystals

		Bakerite[1]	*Datolite*[2]	*Herderite*[3]
Chemical formula		$Ca_8B_{10}Si_6O_{35}6H_2O$	CaB (SiO_4) (OH)	CaBe (PO_4) (OH)
Crystal system		Monoclinic	Monoclinic	Monoclinic
Space group		$P2_1/c$	$P2_1/c$	$P2_1/c$
	a_o	4.82 Å	4.82 Å	4.63 Å
	b_o	7.60 Å	7.62 Å	7.68 Å
	c_o	9.60 Å	9.64 Å	9.80 Å
	β	90°12′	90°09′	90°06′
a_o: b_o: c_o		0.6342:1:1.2632	0.633:1:1.265	0.604:1:1.276
	n_x	1.624 ∓ 0.002	1.626	1.592
Refractive indices	n_y	1.636 ∓ 0.002	1.6535	1.612
	n_z	1.654 ∓ 0.002	1.670	1.621
Birefringence		0.030 ∓ 0.002	0.044	0.029
2V		(—) 83°	(—) 74°	(—) 74°
Habit		Short prismatic thin platy	Short prismatic	Short prismatic
Elongation		($\mp$)	(—)	(—)
Cleavage		None	None	(110)
Twinning		—	None	(100)

1 Optical data is from this study, crystallographic data is from Murdoch (1962).
2 Data from Strunz (1936), Winchell and Winchell (1964), Deer *et al.* (1967), Palache *et al.* (1951).
3 Data from Strunz (1936), Schüller (1953), Murdoch (1962).

CHEMICAL ANALYSIS

Keeping in mind the similarity of the optical and the X-ray diffraction properties of datolite, herderite and bakerite, chemical anayses of the latter were made (Table 4). Spectrometric analyses of bakerite showed that it contains trace amounts of Cu, Pb, Mn and Ag.

There are very few chemical analyses of bakerite in the literature. The results of our chemical analyses agree with those given by Giles (1903) and Kramer and Allen (1956). According to these authors the chemical formula for bakerite is $8CaO{\bullet}5B_2O_3{\bullet}6SiO_2{\bullet}6H_2O$. Palache *et al.* (1951), on the other hand, give different chemical data and therefore a different formula: $Ca_4B_4(BO_4)$ $(SiO_4)_3(OH)$ H_2O. Their formula was derived with the idea that there is a structural similarity between bakerite, datolite and herderite. If this formula is multiplied by two and written in the oxide form the following is found: $8CaO{\bullet}5B_2O_3{\bullet}6SiO_2{\bullet}5H_2O$. Therefore the only difference between the two formulas is the amount of water. For this reason, the probability that (—)H_2O would be given off by bakerite over 105°C and whether the rate and the duration of the heating plays a role over this, was thought useful. That is, the sample was heated for 3, 12 and 24 hours at 105°C and for one hour at 200°C. At the end of these heatings it was seen that the water loss was practically the same. Therefore it is clear that the difference between the two formulas is not due to (—)H_2O.

Table - 3

X-ray diffraction data of bakerite, datolite and herderite (Rad.: CuK_α, Filter: Ni)

Bakerite[1]		*Datolite*[2]		*Herderite*[3]	
d	*I*	*d*	*I*	*d*	*I*
5.962	4	5.94	1	5.99	2
4.814	18	4.84	2	4.77	2
3.729	45	3.75	5	3.79	3
—		—		3.65	1
3.388	30	3.42	3	3.43	5
—		—		3.33	1/2
3.096	100	3.12	10	3.14	10
2.976	28	2.98	4	3.00	6
2.838	70	2.86	7	2.86	8
—		—		2.75	1/2
2.502	40	2.52	5	2.55	6
2.390	8	2.41	1/2	2.40	1
2.282	10	2.30	1/2	2.34	3
2.228	38	2.246	6	2.26	5
2.179	50	2.19	5	2.20	7
2.145	25	2.15	2	2.11	1
2.065	10	2.072	1/2	2.05	1
2.026	7	2.03	1/2	—	
1.982	30	1.996	3	2.00	4
—		—		1.957	1/2
1.890	6	1.896	1/2	—	
1.861	35	1.869	4	1.880	4
1.761	12	1.768	1	1.781	4
1.735	8	1.744	1/2	1.749	1
1.708	20	1.715	2	1.722	3
1.654	12	1.665	1	1.664	1
1.635	30	1.639	4	1.650	5
1.611	7	1.614	1/2	—	
1.556	5	1.558	1/2	1.573	1/2
1.518	8	1.524	1	—	
1.494	8	—		—	
1.473	7	1.480	1/2	—	
1.463	5	1.466	1/2	1.465	1/2
—		—		1.443	1/2
1.422	5	1.427	1/2	—	
1.412	7	1.416	1/2	1.419	1/2
1.353	6				
1.317	7				
1.301	8				
1.262	12				
1.224	10				
1.191	8				
1.180	7				
1.138	8				
1.094	10				

1 Bakerite: Gölcük Plateau, Şerefiye, Turkey (O.B.).

2 Datolite: New Jersey, U.S.A. (Murdoch, 1962).

3 Herderite: Topsham, Maine, U.S.A. (ASTM card.: 6-0338).

One of the formulas mentioned above has 40 oxygens and the other has 41 oxygens. As seen from Table 4, different formulas for bakerite were calculated, based on the different number of oxygens; namely 40 and 41. Calculations show that the formula based on 41 oxygens gave much better cation coefficients. The formula for bakerite therefore is, as pointed out by Kramer and Allen (1956), $Ca_8B_{10}Si_6O3_5 6H_2O$ or $8CaO.5B_2O3.6SiO_2.6H_2O$.

DIFFERENTIAL THERMAL ANALYSIS

Differential thermal analyses were made using 10°/minute heating rate and thermal inert substance Al_2O_3. Runs were made in air and under atmospheric pressure and were continued up to 650°C (Fig. 2). It is clear from the DTA diagram in Figure 2 that bakerite is quite stable thermally and keeps this stability up to 400-450°C giving a small endothermic reaction at 90°C. At this temperature (—) H_2O is given off. At 590°C is a big endothermic reaction and this is typical of bakerite. The results of differential thermal analyses in this work are in accordance with the previous data; namely, bakerite does not lose an important quantity of water between 90-400°C but water loss begins at 400-450°C with an endothermic reaction and reaches its maximum at 590°C.

Table - 4

Chemical analysis of bakerite and calculation of its formula

	Measured weight (%)	*Calcul. (%)*	*Molecular proport.*	*Number of ions (oxygen)*	*Number of ions (cations)*	*Atomic ratios* On basis of 40 oxygens	*Atomic ratios* On basis of 41 oxygens
CaO	35.18	35.34	0.6302	0.6302	0.6302	Ca : 7.7760	Ca : 7.9701
MgO	0.12	0.12	0.0029	0.0029	0.0029	Mg : 0.0357	Mg : 0.0366
SrO	0.04	0.04	0.0004	0.0004	0.0004	Sr : 0.0049	Sr : 0.0051
B_2O_3	27.42	27.54	0.3955	1.1865	0.7910	B : 9.7601	B : 10.0037
SiO_2	28.24	28.36	0.4722	0.9444	0.4722	Si : 5.8264	Si : 5.9719
R_2O_3	0.48	—	—	—	—	—	—
(+)H_2O	8.56	8.60	0.4773	0.4773	0.9546	H : 11.7788	H : 11.9728
(—)H_2O	0.24	—	—	—	—	—	—
Total:	**100.28**						
(—)$H_2O+R_2O_3$	— 0.72						
Total:	99.56	100.00					

Solution:

B : 10.0037
Ca : 7.9701
Mg : 0.0336
Sr : 0.0051 } 8.0088
Si : 5.9719
H : 11.9728

Formula:

$Ca_8B_{10}Si_6O_{35}.6H_2O$

or

$8CaO.5B_2O_3.6SiO_2.6H_2O$

ORIGIN OF BAKERITE

Both the lack of field data and the incomplete studies of the surrounding rocks make it difficult for us to draw a sound conclusion about the origin of bakerite. Nevertheless we might approach the problem in the light of the data from the few samples that we have studied: There are in the region, diabase-spilites that were formed by Na-metasomatism. In these are thin veins of bakerite. Along with bakerite, zeolite (natrolite), chlorite, epidote, and as opaque minerals chalcopyrite, bornite, galena and pyrite were observed. It is highly probable, therefore, that ba-

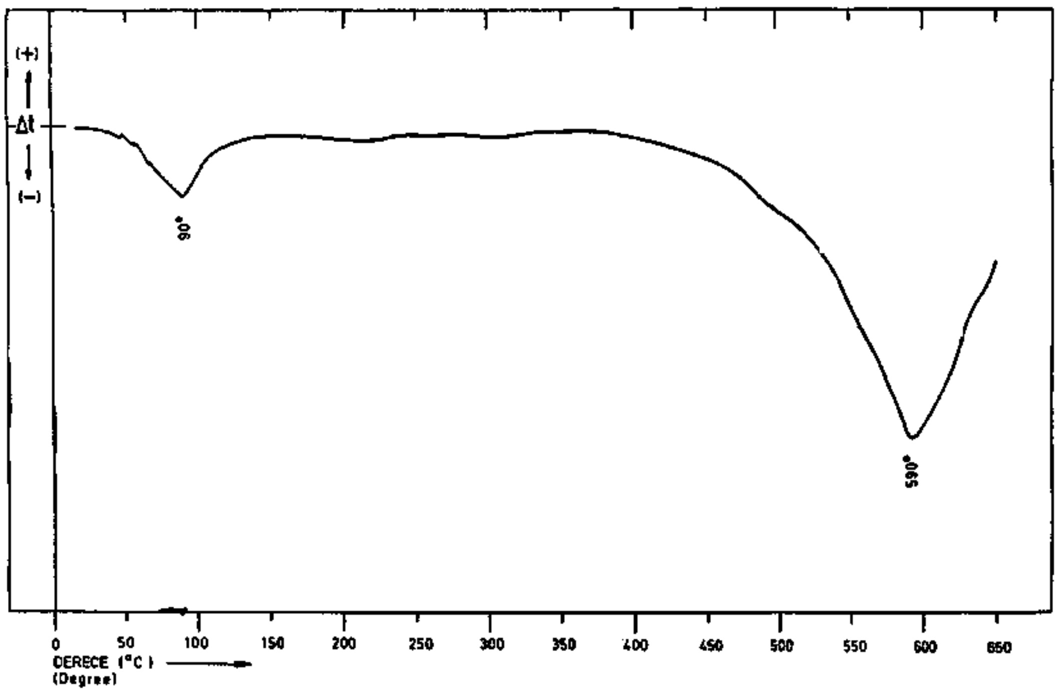

Fig. 2 - Differential thermal analysis diagram of bakerite (heating rate: 10°/min.; thermic inert substance: Al_2O_3).

kerite might have formed from the late-magmatic solutions thatled to Na-metasomatism, that is, albitization and partial mineralization. Considering that bakerite is found associated with the ore minerals of hydrothermal origin, it may be stated that it too was formed by hydrothermal processes.

Manuscript received May 3, 1974

REFERENCES

DEER, W.A.; HOWIE, R.A. & ZUSSMANN, J. (1967): An introduction to the rock-forming minerals. *William Clowes and Sons,* London, 528 p.

DİLEKÖZ, E. & ÇAĞATAY, A. (1973): *M.T.A. Institute, Petrographic report* no. 825/7849 (unpublished), Ankara.

GILES, H. (1903): Bakerite (a new borosilicate of calcium) and howlite from California. *Mineral. Mag.,* 13, pp. 353-355.

KRAMER, H. & ALLEN, R.D. (1956): A restudy of bakerite, priceite, and veatchite. *Amer. Min.,* 41, pp. 689-700.

MURDOCH, J. (1962): Bakerite crystals. *Amer. Min.,* 47, pp. 919-923.

PALACHE, C.; BERMAN, H. & FRONDEL, C. (1951): DANA's system mineralogy, 7 th ed., vol. 2. *John Wiley and Sons, Inc.,* New York-London.

SCHULLER, A. (1953): Die Eigenschaften der Minerale II. *Akademie Verlag,* Berlin.

STRUNZ, H. (1936): Datolith und Herderit. *Zeit. Kryst.* (A), 93, g. 146-150.

WINCHELL, A.N. & WINCHELL, H. (1964): Elements of optical mineralogy and introduction to microscopic petrography, part II. *Descriptions of minerals. John Wiley and Sons, Inc.,* New York.