

# CRYSTALLOGRAPHY OF JADEITE CRYSTALS FROM NEAR CLOVERDALE, CALIFORNIA

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## ABSTRACT

Good crystals of jadeite, a few doubly terminated, have been discovered by Dr. John Peoples of Petaluma, California, along the Russian River near Cloverdale, California. *Optical data:*  $\alpha=1.640$ ,  $\beta=1.645$ ,  $\gamma=1.652$ , all  $\pm 0.003$ ; biaxial positive;  $2V=67^\circ$ ; elongation positive; nonpleochroic; extinction angle  $Z/\epsilon=40^\circ$ ;  $Y=b$ . *Crystallographic data:*  $a:b:c=1.1026:1:0.6110$ ;  $\beta=107^\circ 38\frac{1}{2}'$ ; Forms:  $b\{010\}$ ,  $a\{100\}$ ,  $i\{130\}$ ,  $m\{110\}$ ,  $y\{101\}$ ,  $u\{111\}$ ,  $s\{\bar{1}11\}$ ,  $\Delta\{3\bar{1}1\}$ . Twin index, 1; obliquity,  $1^\circ 34'$ . *X-ray data:*  $a_0=9.48$ ,  $b_0=8.59$ ,  $c_0=5.23$  KX;  $\beta=107^\circ 26'$ ;  $a_0:b_0:c_0=1.104:1:0.609$ ; space group  $C 2/c$ . *Chemical analysis:* indicates composition of 94% jadeite, 6% diopside.

## INTRODUCTION

Good crystals of jadeite are rarities. It was with considerable pleasure therefore, that the author received a few crystals of the mineral from Dr. John W. Peoples of Petaluma, California, through the good services of Dr. Leland Wyman of Boston University. The goniometric, optical, and x-ray investigation which followed indicated that the material was indeed jadeite, and Dr. Peoples was contacted in the hope of getting more and better crystals. He graciously put the best of his material at the author's disposal, and the present paper results from a study of the crystals and matrix specimens which he supplied.

## MORPHOLOGY

Goniometric examination of approximately 30 crystals yielded the elements and forms listed in the following angle table.

### JADEITE. MONOCLINIC; PRISMATIC-2/*m*

$$a:b:c = 1.1026:1:0.6110; \beta = 107^\circ 38\frac{1}{2}'; p_0:q_0:r_0 = 0.5541:0.5823:1$$

$$r_2:p_2:q_2 = 1.7174:0.9517:1; \mu = 72^\circ 21\frac{1}{2}'; p_0' = 0.5815, q_0' = 0.6110, x_0' = 0.3181$$

Forms:	$\phi$	$\rho$	$\phi_2$	$\rho_2$	$C$	$A$
<i>b</i> 010	0°00'	90°00'	—	0°00'	90°00'	90°00'
<i>a</i> 100	90 00	90 00	72°21'	90 00	72 21	0 00
<i>i</i> 130	17 36	90 00	0 00	17 36	84 44½	72 24
<i>m</i> 110	43 35	90 00	0 00	43 35	77 56	46 25
<i>y</i> 101	90 00	41 58½	24 19½	90 00	24 19½	48 01½
<i>u</i> 111	55 49	47 24	48 01½	65 34	33 56½	52 29½
<i>s</i> $\bar{1}11$	-23 19	33 38½	104 45½	59 25½	43 22½	102 40
$\Delta$ $3\bar{1}1$	-66 48½	57 12	144 58	70 40½	73 37½	140 35½

*Description of Forms.* The two dominant forms on most of the crystals were the third order prism {110} and the fourth order prism {111}. On one crystal habit {100} was the principal form, but this was observed on only five crystals. On the crystals of the first habit minute additional forms were observed in fair position, as is summarized in the tabulation below. The crystals which were tabular on {100} are not included in the tabulation because of the bad quality of their reflections.

## MEASURED AND CALCULATED ANGLES FOR JADEITE FORMS ON 7 BEST CRYSTALS

Form	Range in Size*	Range in Qual.*	No. Xls.	No. Times	Meas. $\phi$ Range	Meas. $\rho$ Range	Calc. $\phi$	Calc. $\rho$
010	3-4	4-5	4	5	0°00'-8°08'	90°00'	0°00'	90°00'
100	2-4	3-5	4	4	87 01-93 17	90 00	90 00	90 00
130	4	5	1	1	17 42	90 00	17 46	90 00
110	1-2	3-4	7	23	38 34-44 54	90 00	43 35	90 00
101	5	5	2	2	90 20	41 43	90 00	41 58½
111	2-4	1-4	7	14	55 36-56 54	47 06-47 26	55 49	47 24
$\bar{1}11$	5	5	1	1	-30 18	32 30	-23 19	33 38½
$\bar{3}11$	4	5	1	1	-71 00	55 30	-66 48½	57 12
Summary of best weighted values								
					$\phi$	$\rho$		
					110	43°35'	90°00'	
					111	55 49	47 24	

\* Size is graduated from (1) largest to (5) smallest; quality of signal is graduated from (1) excellent to (5) very bad.

*Choice of unit.* It may be noted from the elements that  $x_0'$ , 0.3181, is greater than  $p_0'/2$ , 0.2907. This means the convention has been disregarded that the pole of (001) should be that node in the zone [010] which is closest to the center of the projection when the axis of rotation is [001]. Two reasons for this choice follow. The only important terminal form receives the indices of {111} when the third pinacoid (001) is chosen as was done here. If the node of the zone [010] closest to the center of projection was chosen as the base, the indices of the only important terminal form would be  $\{\bar{2}11\}$ . Therefore, from the viewpoint of simplicity of indices the chosen orientation is to be preferred. A second reason for this choice derives from the designation of the lattice mode which results. Before x-ray work was done it was decided that the two choices indicated

that the lattice mode would be *C*-centered in the chosen orientation and *I*-centered in the other orientation. Since *C*-centering is conventionally chosen, it was felt even more strongly that the chosen orientation was the desirable one. As will appear later, *x*-ray examination of single crystals demonstrated that this view of the lattice mode is correct.

*Calculation of elements.* Since the calculation of the elements for jadeite involves a procedure which is not too common, it may be desirable to develop the method here. The only satisfactory terminal form for calculation purposes was the fourth order prism  $\{111\}$ . Phi and rho were determined with fair precision for this form on several crystals. The best average values are

$$\text{Phi}_{111} = 55^{\circ}49'; \quad \text{rho}_{111} = 47^{\circ}24'$$

$$x' \text{ coordinate on gnomonic projection} = \sin \phi \tan \rho = 0.8996 \quad (1)$$

$$y' \text{ coordinate on gnomonic projection} = \cos \phi \tan \rho = 0.6110 = q_0' = c \quad (2)$$

but:

$$x'_{111} = x_0' \text{ (the } x' \text{ coordinate of the base, which does not exist in these crystals)} + p_0'. \quad (3)$$

The determination of  $p_0'$  and  $x_0'$  from the  $x'$  value of  $\{111\}$  is possible if a good phi value is known for an  $\{hk0\}$  form. In this case the phi value for  $\{110\}$  was dependable.

$$\text{Phi}_{110} = 43^{\circ}35'.$$

Since the poles of  $\{110\}$  lie on the zero layer line of the reciprocal lattice when the *c*-axis is vertical while  $\{111\}$  lies on the gnomonic representation of the first layer line, the plotted pole of (110) does not pass through the pole of (001) but through the point (000) on the zero layer.

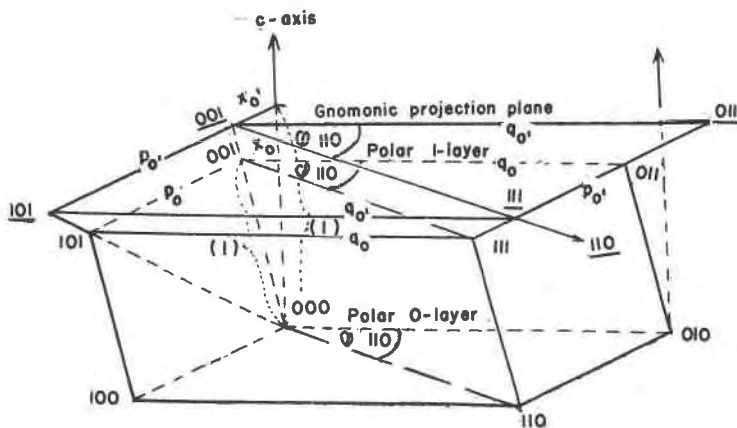


FIG. 1. Relation of (110) on 0-layer of polar lattice to (111) of 1-layer of polar lattice and (111) of the gnomonic projection plane.

If we imagine the pole of (001) to be shifted down to the origin (000), or vice versa, the directions to the faces of the form {110} would pass through the nodes of {111}, for they would be coincident. (Fig. 1). Thus we see that the

$$\tan \phi_{110} = p_0'/q_0' = p_0/q_0. \quad (4)$$

We have the  $\phi$  of {110}, and we have  $q_0'$  (formula (2)). Thus, we have  $p_0' = 0.5815$ . Substituting in formula (3):

$$0.8996 = x_0' + 0.5815; \quad x_0' = 0.3181.$$

With  $x_0'$ ,  $p_0'$ , and  $q_0'$  known, the calculation of polar and linear elements follows the usual pattern.

#### COMPARISON OF JADEITE ELEMENTS WITH THOSE OF OTHER PYROXENES

The following tabulation gives the elements of jadeite and of other pyroxenes for comparison. The values for the pyroxenes are excerpted from Dana (1892).

	<i>a</i>	<i>b</i>	<i>c</i>	$\beta$
Jadeite (Wolfe)	1.1026	1	0.6110	107°38½'
Jadeite (Penfield in Kunz)	1.103		0.613	107 44½'
Russian and others (average)	1.0931		0.5895	105 48½'
Diopside	1.0913-1.0922		0.5843-0.5895	105 25-105°51'
Augite (dark green)	1.0955		0.5904	105 46
Augite (yellow)	1.0921		0.5893	105 50
Acmite	1.0996		0.6012	105 49
Spodumene	1.1238		0.6355	110 20

It is to be noted that the *c* value for jadeite is closest to that of the NaFe pyroxene acmite, while the *a* value corresponds to the values of all listed pyroxenes except spodumene. The values for jadeite determined by Penfield (1906) are amazingly close to those of the present author. The crystals examined in this work are presumably of better quality than those possessed by Penfield. My values were determined before the record of Penfield's work was examined, and although the new values are very close to his, the new values for *c* and for  $\beta$  are probably preferable because of the better quality of the crystals and because a chemical analysis of the California crystals (which follows) indicates the purity of the material as jadeite.

The author was unable to examine the original work on jadeite by Kunz in which the crystallographic description was given by Penfield (Pt. 3-Jade as a mineral; p. 78). A transcribed quotation from that work

reads: "Specimen 51, said to be from Tibet, yielded two measurable crystals, each about 2 mm. long and 0.5 mm. across and terminated on one end. Colorless with vitreous luster. Forms:  $\{100\}$ ,  $\{110\}$ ,  $n \{130\}$ ,  $s \{\bar{1}11\}$ ."

The zone  $[001]$  of most of the California crystals was striated, and a series of weak reflections in addition to the strong ones from  $\{110\}$  could be picked up from line faces in the zone. The only weak reflection which was indexed was  $\{130\}$ , which is in agreement with Penfield's description. Since Penfield arrived at almost identical elements to those of this paper the indexing of his  $s$  plane as  $\{\bar{1}11\}$  is proper although his one terminal

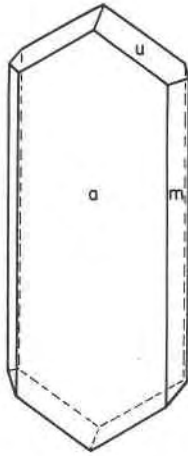


FIG. 2. Jadeite. Habit of first generation crystals.

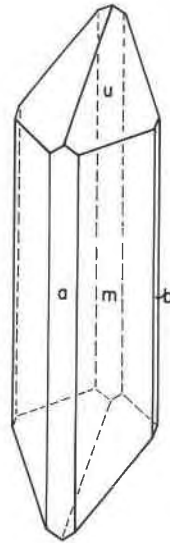


FIG. 3. Jadeite. Habit of Second generation crystals.

form was observed but once on my seven best crystals. My dominant terminal form is  $u \{111\}$ , not  $s \{\bar{1}11\}$ .

*Crystal habit.* Two distinctly different habits were observed, Figs. 2 and 3. Figure 2 represents the rather platy rectangular habit which is characteristic of crystals formed during the early stages of crystallization. Figure 3 pictures the elongated prismatic crystals which formed during the last stages of crystallization. The first or front pinacoid  $\{100\}$  is the dominant form in habit 1, while in habit 2  $\{100\}$  is very much reduced in size or absent, and  $\{110\}$  becomes dominant. Doubly terminated crystals were very rare but were noted for each habit.

*Twinning.* Twinning on  $\{100\}$  is extremely common amongst the py-

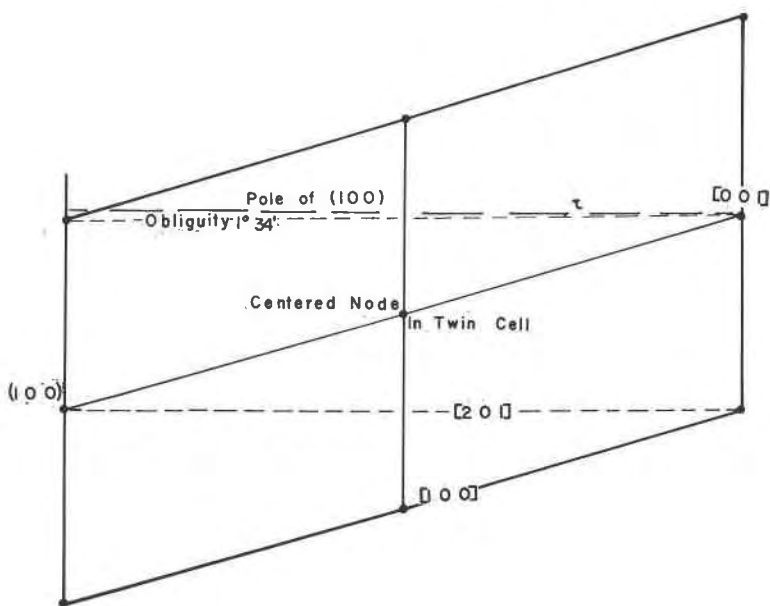


FIG. 4. Geometry of twinning in jadeite.

roxenes. From Fig. 4 it will be seen that the lattice row  $[201]$  in the jadeite lattice is almost, but not exactly perpendicular to the front pinacoid (the twin plane) and, likewise, to the  $c$  axis  $[001]$ . The deviation from normality is the *obliquity of the twin*, according to the Friedel (1926) approach. Since this deviation is  $90^\circ 00'$  minus the angle  $\tau$  between  $[001]$  and  $[201]$ , the calculation of the obliquity is very simple in this case, using the formula:

$$\cos \tau = c^2 + ca(w_1u_2) \cos \beta / T_{u_1v_1w_1} \cdot T_{u_2v_2w_2}$$

where  $[001] = u_1v_1w_1$ ;  $[201] = u_2v_2w_2$ ;  $a, b, c, \beta$  = the linear elements;  $T_{u_1v_1w_1}$  = the periodicity along  $[001]$ ; and  $T_{u_2v_2w_2}$  = the periodicity along  $[201]$ .

If we use the rounded elements for augite of Rath (Dana, 1892),

$$a:b:c = 1.0921:1:0.5893; \quad \beta = 105^\circ 50'$$

we get an obliquity of  $10' 51''$ , which is an exceedingly low value. Since there is a node at the center of the multiple twin cell, the face-centered twin lattice repeats all of the nodes of the simple lattice, and the index of the twin is thus one (1). The low index of the twin coupled with the exceedingly low obliquity makes twinning on  $\{100\}$  highly expectable, according to the Friedel approach. It should also be pointed out that the complimentary twin law of twinning by a rotation of  $180^\circ 00'$  about  $[201]$  is likewise expectable.

If we use the jadeite elements determined by the author, the obliquity of this twinning by pseudo-reticular merohedry is considerably greater:  $1^{\circ} 34'$ . It is interesting here to mention a rather simple method of checking the calculation of the obliquity. It is apparent that the pole of the lattice row [201] must lie on the zone plane of the  $\{h0l\}$  forms and must also be  $90^{\circ} 00'$  from  $(\bar{1}02)$ . The *rho* angle of  $(\bar{1}02)$  is readily calculated from the projection elements (which were the fundamental elements from which the linear elements were obtained). This value is  $1^{\circ} 34'$  with a *phi* value of  $+90^{\circ} 00'$ . The pole of [201], therefore, lies in the southern hemisphere of projection and an angular distance of  $1^{\circ} 34'$  from the pole of (100), and this angle defines the obliquity, as was indicated above. It should be pointed out that the linear elements are rounded values obtained from the projection elements; and if the logarithmic values obtained before rounding had not been used, the value of  $1^{\circ} 34'$  would not have been reproduced in each case.

Although the index of the twinning in jadeite is 1 as was the case in augite, the obliquity is much greater, and twinning is not as expectable, from the geometrical viewpoint. The fact that I have not observed twinning, either optically or morphologically indicates that the geometrical approach to twinning is sound in this case, as it has been in most cases where applied. Wolfe (1953) states: "The physical chemical forces which are involved in the accretion of ions, atoms, or molecules to form crystals have been studied of late; but as yet good quantitative measurements are not available. Since we are not clear as to the nature and magnitude of these forces, we cannot ascertain the precise nature of the equilibrium conditions involved in the growth of a single crystal. Neither, then, can we know at present what variations in the physical-chemical environment would produce first one position of growth equilibrium and then another to develop a twin. We are constrained to approach the subject of twinning, then, from a geometrical view." In essence these are the thoughts of Friedel on the best approach now available to twinning.

#### X-RAY DATA

Single crystal runs were made on crystals of the platy habit and of the prismatic habit. In addition, since some of the prismatic type crystals were colorless along most of their length but were colored green on the tips, single crystal runs were made of the green tipped and the colorless portions of the same crystal. The pictures of the platy crystals gave rather broad spots, making accurate measurement impossible, but aside from this fact no significant difference could be found in the dimensions of the unit cells of the three types of crystal material.

Rotation about the  $c$  axis gave the following data:

$$\begin{aligned}c_0 &= 5.25 \text{ KX} \\d_{100} &= 9.04 \\b_0 &= 8.60\end{aligned}$$

Rotation about the  $b$  axis yielded:

$$\begin{aligned}d_{001} &= 4.99 \text{ KX} \\d_{100} &= 9.05 \\b_0 &= 8.58 \\d_{\bar{1}01} &= 5.06 \\ \mu &= 72^\circ 34'\end{aligned}$$

We have taken as the best fundamental values for the unit cell:

$$a_0:b_0:c_0 = 9.48:8.59:5.23 = 1.104:1:0.609; \quad \beta = 107^\circ 26'$$

which compare favorably with our goniometric values:

$$a:b:c = 1.1026:1:0.6110; \quad \beta 107^\circ 38\frac{1}{2}'.$$

Dr. Hatten S. Yoder, Jr. (1950) calculated the principal periodicities for jadeite from powder pictures, assuming that the elements of Penfield, given earlier in this paper, were correct. His values in Ångstroms are:

$$a_0 = 9.45; \quad b_0 = 8.57; \quad c_0 = 5.25,$$

which is in good agreement.

There can be no doubt that the crystal class for jadeite is prismatic  $2/m$ . The 2-fold axis and symmetry plane are seen on many of the crystals. In addition a glide plane is indicated by the  $x$ -ray study, which confirms the existence of the symmetry plane. As was mentioned earlier, the lattice of jadeite is centered, and the orientation was chosen which makes the lattice centered on  $\{001\}$ , resulting in the presence of reflections which conform to the criteria:  $\{hkl\}$  present when  $h+k=2n$ . The plane  $\{010\}$  is a glide plane with a glide component of  $c/2$ , resulting in the occurrence of reflections of those  $\{h0l\}$  planes for which  $l$  is even. The space group is, therefore,  $C 2/c$ , as was suggested by Yoder.

*Impact of space group and elements on form development in jadeite.* Friedel (1904) developed the thesis that the importance of a form is directly proportional to its reticular density or the spacing between planes. In this work he demonstrated that the lattice mode must be considered in determining spacings, as is well known now from  $x$ -ray studies. Donnay and Harker (1937) demonstrated that not only the lattice mode but also the effect of glide planes and screw axes must be considered in ascertaining the spacings within a particular crystal. It is interesting to remember that if the importance of a form in a particular crystal is directly proportional to its spacing as determined by the direct lattice



elements and the space group, the *importance of that form is inversely proportional to the periodicity from the origin of the reciprocal lattice to the node of the reciprocal lattice defined by the indices* (Wolfe, 1953). Since indices of faces (which is the customary method of designating a plane in the direct lattice) are coordinates within the reciprocal lattice of the normals to direct lattice planes, it would seem desirable to express the rule in terms of this reciprocal relationship. A particular periodicity in any three dimensional homogeneous network can be defined in terms of three coordinates (the indices in this case) in three different reference directions in that network or lattice. The three unit lengths used in defining the reciprocal lattice of morphological crystallography are  $p_0$ ,  $q_0$ , and  $r_0=1$  ( $a^*$ ,  $b^*$ ,  $c^*$  of  $x$ -ray crystallography). Any particular periodicity defined by the indices  $hkl$  may then be calculated by the following standard formula:

$$T_{hkl}^2 = h^2 p_0^2 + k^2 q_0^2 + l^2 + 2klq_0 \cos \lambda + 2lh p_0 \cos \mu + 2hk p_0 q_0 \cos \nu.$$

Since  $\lambda$  and  $\nu$  are  $90^\circ 00'$  in the monoclinic system, the formula is considerably simplified for the calculation of a reciprocal periodicity in this case.

Let us list those forms whose indices include no numbers higher than 2 and give the proper indices of those forms in view of the space group  $C2/c$ ; give the periodicities of those forms, assuming  $p_0=0.5541$ ,  $q_0=0.5822$ ,  $r_0=1$ ; a column will be devoted to the summation of indices, another to the theoretical importance of the form, and a final one to the observed importance of the form as nearly as it could be judged.

A perusal of the above tabulation demonstrates that the five best developed forms which were seen in good position on the jadeite crystals are included in the first eight forms with the shortest periodicities in the reciprocal lattice, and seven of the eight observed forms are included in the first eight of the forms listed according to increasing periodicities in the reciprocal lattice.

It will be seen that the only importance that can be ascribed to the rule of *simplest summation of indices* as a guide to the importance of forms is as follows. *The most important forms in any particular zone are those with the smallest summation of proper* (based on space group criteria) *indices*. The theoretical relative importance of forms with the same summation of indices in different zones can best be approached as was done above. It is obvious that this is but another approach to and demonstration of the Donnay-Harker principle. It is not necessary to demonstrate here that lattice spacings, in general, reflect physical bonding forces during the growth of a crystal, and that consequently the geometrical approach is an approximation to the physical approach which still eludes scientific precision.

Simplest indices	Proper indices	Summation of indices	Reciprocal periodicity	Form importance theoretical	Form importance actual
001	002	2	2		
010	020	2	1.16	4	4
100	200	2	1.11	2	2
110	110	2	0.80	1	1
120	240	6	2.58		
210	420	6	2.50		
130	130	4	1.83	8	5
101	202	4	2.56		6
102	204	6	4.46		
201	402	6	3.40		
$\bar{1}01$	$\bar{2}02$	4	1.97	10	
$\bar{1}02$	$\bar{2}04$	6	3.82		
$\bar{2}01$	$\bar{4}02$	6	2.50		
011	022	4	2.31		
012	024	6	4.17		
021	042	6	2.99		
111	111	3	1.41	5	3
112	112	4	2.31		
121	242	8	3.68		
211	422	8	3.63		
221	221	5	2.06		
$\bar{1}11$	$\bar{1}11$	3	1.14	3	7
$\bar{1}12$	$\bar{1}12$	4	1.91	9	
$\bar{1}21$	$\bar{2}42$	8	2.79		
$\bar{2}11$	$\bar{4}22$	8	2.72		
$\bar{2}21$	$\bar{2}21$	5	1.71	6	
$\bar{3}11$	$\bar{3}11$	5	1.76	7	8

## PHYSICAL PROPERTIES

The following physical properties were noted for crystals of jadeite.

Hardness—6.

Cleavage—{110} good.

Color—first generation crystals are dull white; second generation crystals are colorless with sharp light to dark green tips.

Luster—dull lithic on first generation; vitreous on second generation.

Streak—colorless.

Specific gravity—3.245.

*Optical properties*

Biaxial positive.

 $\alpha=1.640$ ,  $\beta=1.645$ ,  $\gamma=1.652$ , all  $\pm 0.003$ . $2V=67^\circ$ .

Elongation-positive.

Non pleochroic. No abnormal interference colors.

No dispersion of the optic axes.

 $Y=b$ ;  $Z \wedge c=40^\circ$ .

Comparison of optical properties.

Jadeite-Wolfe  $\alpha=1.640$ ,  $\beta=1.645$ ,  $\gamma=1.652$ Jadeite-Larsen and Berman  $\alpha=1.654$ ,  $\beta=1.659$ ,  $\gamma=1.667$ Diopside-Larsen and Berman  $\alpha=1.664$ ,  $\beta=1.671$ ,  $\gamma=1.694$ 

## CHEMISTRY

Dr. George Switzer of the Smithsonian Institute learned of the occurrence of the jadeite crystals through Dr. Yoder of the Geophysical Laboratories and contacted Dr. Peoples for some material. Crystals were supplied for a chemical analysis. Unfortunately, the optical, goniometric, and  $x$ -ray studies of this paper were not made on this material, but it seems probable that all of Dr. People's material was homogeneous. Since Drs. Switzer and Fahey are working on the correlation of optical properties with chemical analyses of pyroxenes, they sent the sample to the University of Minnesota laboratory for analysis. Dr. Switzer has kindly released this analysis to make the treatment of the Cloverdale material as complete as possible. The analysis follows:

## ANALYSIS OF JADEITE FROM NEAR CLOVERDALE, CALIFORNIA

	1	2	3	4	5	6	7	8
SiO <sub>2</sub>	61.66	61.74	8.215	59.20	7.88	59.20	59.44	55.48
Al <sub>2</sub> O <sub>3</sub>	21.81	21.84	1.71	23.26	1.82	23.71	25.22	
TiO <sub>2</sub>	.05	.05						
Fe <sub>2</sub> O <sub>3</sub>	.32	.32						
FeO	.24	.24	.03					
MnO	.05	.05						
MgO	.98	.98	.19	1.04	.21	1.12		18.62
CaO	1.38	1.38	.20	1.47	.21	1.55		25.90
Na <sub>2</sub> O	12.27	12.29	1.58	13.08	1.69	14.42	15.34	
K <sub>2</sub> O	.57	.57	.01					
H <sub>2</sub> O(+)	.44	.44						
H <sub>2</sub> O(-)	.10	.10						
Total	99.87	100.00				100.00	100.00	100.00

Columns: 1. Analysis of jadeite from near Cloverdale, California, by University of Minnesota laboratory; 2. Column 1, recalculated to 100%; 3. Molecules in unit cell assuming  $V_0=406.3$ ,  $d=3.245$  (measured on Berman balance); 4. Approximate analysis

If we take the average content of the jadeite molecule to be 3.2 in column 3 and the average content of diopside to be 0.195, the percentage of jadeite molecules is 94 and of diopside, 6. It is clear that there should be 4 molecules of  $\text{J}_{94}\text{Di}_6$  in the unit cell, but because of the probable admixed quartz, the analysis is high in  $\text{SiO}_2$  and low in the other jadeite-diopside components. A fair calculated approximation of the quartz content is 6%. If we recalculate the analysis for its jadeite-diopside composition, eliminating 6% quartz, the adjusted analysis would appear as in column 4. This is, admittedly, an approximation (as is indicated by the deficiencies of theoretical molecular content shown in column 5), but it is certainly closer to the true analysis than that given in column 1.

#### OCCURRENCE

Dr. J. W. Peoples, the original discoverer of the jadeite from near Cloverdale, California, has kindly supplied the following information concerning the locale of the discovery. The source material is comprised of four boulders lying in the stream bed of the intermittent Russian River to the west of a point  $2\frac{1}{4}$  miles north of the Sonoma County-Mendocino County line along the main north south route U. S. 101. There is a 60 foot drop from the road to the river at this place, and Dr. Peoples believes the boulders, which averaged about two feet in diameter, were rolled over the bank into the channel during road construction. There seems to be nothing of value left, as far as jadeite is concerned, at the locality. The source outcrops for the boulders have not been located as yet, but it is suspected that the boulders have not traveled far.

The jadeite occurs in light colored veinlets in a glaucophane rock. The veinlets vary in thickness from minute to as much as two inches across. No single veinlet is continuous for distances of much more than six times the thickness of the veinlet; the ends may pinch out or may end abruptly.

Serpentine seems to be the earliest mineral in the veinlets. Jadeite, platy on {100}, formed secondly and is probably the most abundant mineral in the veinlets. At the time the jadeite was forming the veinlets were apparently open spaces which the jadeite and calcite filled randomly without parallel orientation of adjacent crystals. Second generation jadeite, elongated parallel to [001] with predominant {110} grew upon the first jadeite, projecting into the remaining open space. In some cases, but not all, the tips of these second generation crystals are a very lovely transparent light emerald green in contrast with the water-clear lower

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of jadeite from column 1, assuming a 6% contamination by water-clear quartz which was present in the jadeite matrix; 5. Molecules in unit cell of adjusted analysis listed in column 4; 6. Theoretical composition of  $\text{J}_{94}\text{Di}_6$ ; 7. Theoretical composition of jadeite  $\text{NaAl}(\text{SiO}_3)_2$ ; 8. Theoretical composition of diopside  $\text{CaMg}(\text{SiO}_3)_2$ .

parts of the prisms. Before this generation of jadeite was completely crystallized, water-clear pseudo cubic quartz crystals began to form concomitantly, and they appear as partially embedded, partially projecting crystals. A few very minute but choice crystals of water clear jadeite seem to have formed during the very last stages of this crystallization. The remaining open space in the veinlets was finally almost completely filled with calcite. Albite appears to be a late cavity filling in some cases. It is to be hoped that a more comprehensive and meaningful paragenesis can be worked out when and if the jadeite is found *in situ*.

#### ACKNOWLEDGMENTS

The author cannot help but express a most sincere admiration for amateur mineral collectors of the type represented by Dr. Peoples. Very few professionals would have the curiosity to examine boulders in a dry stream bed, and if they had, they probably would not have pursued that curiosity to the point of etching the specimens with acid to reveal the possibility of unusual crystals within. Very few professionals, with their concern for professional duties, would more than glance at the material, but Dr. Peoples realized that something different was present and continued persistently until an identification was finally made and the foregoing study was undertaken. He generously supplied material and information and has waited as patiently as possible for four years to see the results of the study.\* I must also acknowledge that without the help of Dr. Wyman, another amateur mineralogist, the specimens would never have reached my door.

I should also like to express my appreciation for the chemical analysis which appears in this paper which was made available by Dr. George Switzer. Miss Daphne Riska was of considerable help in the determination of the physical properties.

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\* Deceased September 22, 1954.