

IMPACT OF LIQUID QUENCHING ON ALUMINIUM-SILVER ALLOYS

P. RAMACHANDRARAO AND T. R. ANANTHARAMAN

Department of Metallurgy, Banaras Hindu University, Varanasi-5

INTRODUCTION

SEVERAL metastable and new intermediate phases have been detected in binary alloys quenched from the melt by the Duwez technique of liquid quenching,¹ also referred to as "Splat Cooling", which produces cooling rates of the order of 10^6 – 10^8 degrees C/sec.² Some alloys have been found to exhibit amorphous solidification under such drastic rates of cooling. In many binary alloys a striking extension of the limits of solid solubility of terminal solid solutions has also been reported. The many interesting results obtained by this technique have been reviewed recently.^{3,4}

The present work deals with the influence of liquid quenching on the solid solubility of silver in aluminium and on the constitution of two-phase alloys on the aluminium-rich side of the aluminium-silver system. The equilibrium diagram for the aluminium-silver system is well established (Fig. 1) and shows the

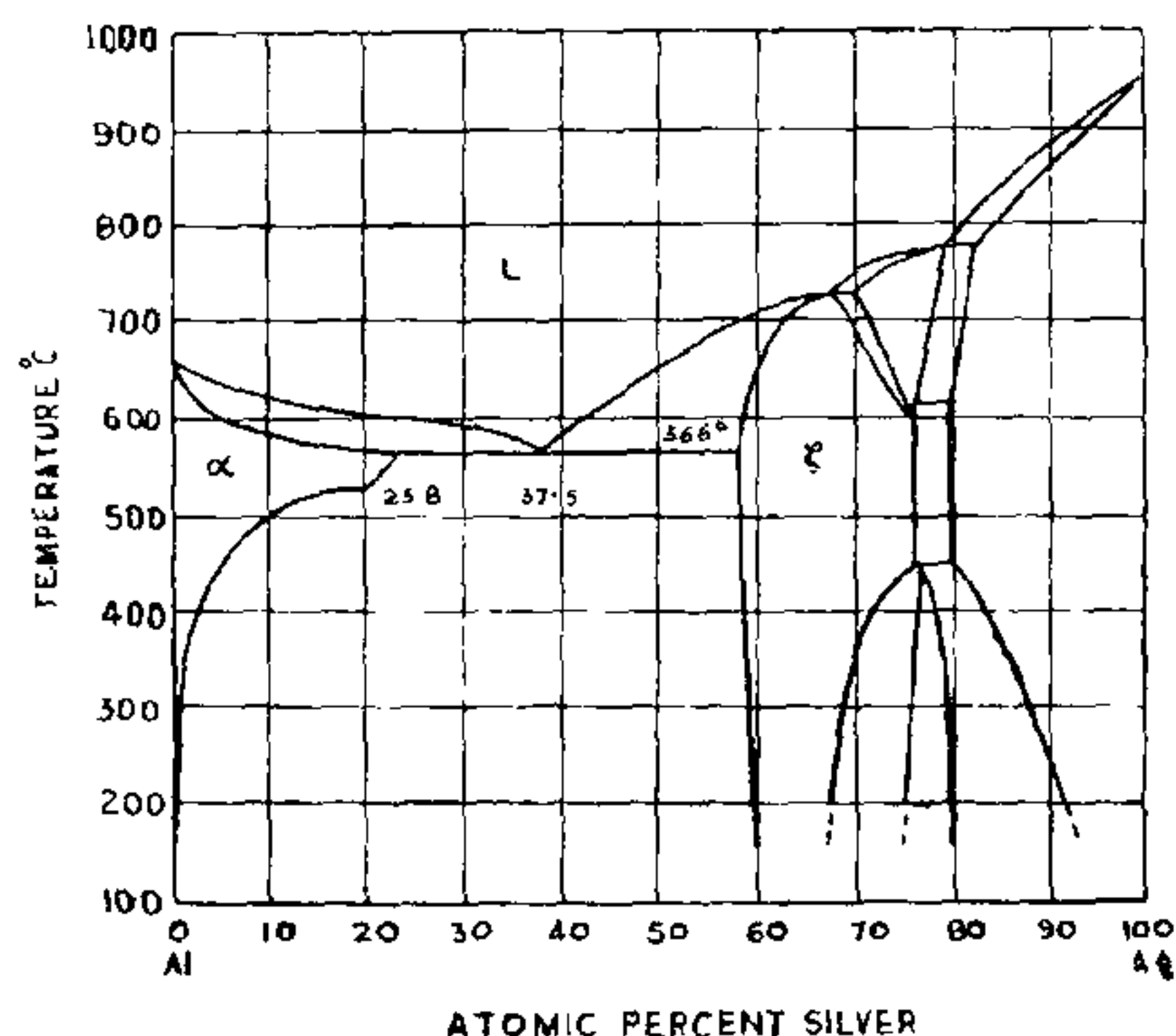


FIG. 1. Aluminium-silver equilibrium diagram.

existence of three intermediate phases in addition to the two face-centred cubic (f.c.c.) terminal solid solutions.⁵ The lattice parameters of silver solid solutions have been found to decrease linearly with increasing amounts of aluminium in solution. The variation of lattice parameters of aluminium solid solutions has, however, been controversial. Earlier investigators⁶ have stressed the importance of quenching from high temperatures at a rapid rate to prevent the separation of the

hexagonal close-packed (h.c.p.) zeta (ζ) phase in alloys containing more than 10 atomic % silver in solution. The effect of liquid quenching on the structure of ζ phase has also been investigated in the present study.

EXPERIMENTAL PROCEDURE

Thirteen alloys (Table I) prepared from aluminium of 99.999+ % purity and silver of 99.95+ % purity and covering the entire range of α , $\alpha + \zeta$ and ζ fields in the aluminium-silver system (Fig. 1), were investigated. Weighed quantities of the elements were melted in graphite crucibles by induction heating under argon atmosphere. The slugs were remelted under argon and cast into wires by sucking the liquid up into preheated 1mm. dia. quartz tubing and quenching into water.

TABLE I

Estimated distribution of phases at room temperature in aluminium-silver alloys quenched from the melt

At % Silver	Observed intensities of X-ray Reflections	
	α (f.c.c.)	ζ (h.c.p.)
5	vs	—
10	vs	—
15	vs	—
20	vs	—
25	vs	—
30	vs	vw
35	vs	w
40	s	m
45	ms	ms
50	w	s
55	vw	vs
60	—	vs
65	—	vs

vs=very strong; s=strong; ms=medium strong; m=medium; w=weak; vw=very weak.

The principle of liquid quenching has been described earlier.¹ Essentially it consists of loading 50–100 mg. of the alloy wire into a graphite nozzle and quickly heating it by induction to a temperature about 50 degrees C above the liquidus temperature for each alloy, under an atmosphere of argon. The molten alloy is then ejected by a blast of helium on to a copper sheet held on the inner periphery of a rotating wheel.

The product of liquid quenching in the present work was generally an ellipsoidal foil with irregular edges, of an average length of 2–4 cms. and a width of 0.5–1.0 cm. The

thickness varied from less than a micron at the edge to a maximum of 15 microns at the center of the foil. These foils were examined with or without the substrate in a Philips X-ray Diffractometer. Debye-Scherrer patterns were also obtained by sticking the alloy flakes on to a quartz fibre with cleavage and mounting the assembly in a Philips 114.6 mm. dia. camera. Filtered Cu K_{α} radiation ($\lambda_{CuK_{\alpha_1}} = 1.5405 \text{ \AA}$) was used to obtain the diffraction patterns at room temperature. Attention was mainly focused on the high angle (422) reflection in order to follow the change in lattice parameter of the aluminium solid solution with increasing amounts of silver in solution. This reflection was chosen because of its high Bragg angle, good intensity and clear resolution of a_1 and a_2 .

EXPERIMENTAL RESULTS

Table I gives the relative intensity of X-ray reflections from the α (f.c.c.) and ζ (h.c.p.) phases in stabilised liquid-quenched aluminium-silver alloys. The as-quenched alloys were observed to change at room temperature with regard to the proportion of phases in two-phase alloys and were generally stabilised after a short time. There was no evidence for the occurrence of any new phase in the composition range investigated.

The values of lattice parameters of the aluminium solid solutions were calculated from the (422) reflections after separating the a_1 and a_2 components by the method due to Anantharaman and Christian⁷ and are plotted as a function of the atomic percentage of silver in Fig. 2 along with the results of some earlier investigators.

The ζ phase obtained on quenching the 65 at.% silver-aluminium alloy had an axial ratio of 1.608 while the corresponding annealed alloy gave a value of 1.600. The axial ratios were arrived at by employing the method due to Otte and Esquivel.⁸

DISCUSSION OF RESULTS

As pointed out earlier,⁶ conventional methods of quenching seem to fail to retain the super-saturated aluminium solid solution beyond 10 at.% silver in the aluminium-silver system. The quenched product generally consists of two phases. Fukano and Ogawa⁹ have reported that it is possible to retain an aluminium solid solution with 20 at.% silver by quenching evaporated films of about 800 \AA thickness on rock salt heated to 440 degrees C. The data of Table I clearly establish the efficacy of liquid quenching in retaining aluminium solid solutions containing upto, if not more than,

25 at.% silver. The maximum limit of solid solubility according to the equilibrium diagram (Fig. 1) is exceeded, although there is no spectacular extension of solid solubility due to sp \dot{r} at cooling as in some other binary systems.^{3,4}

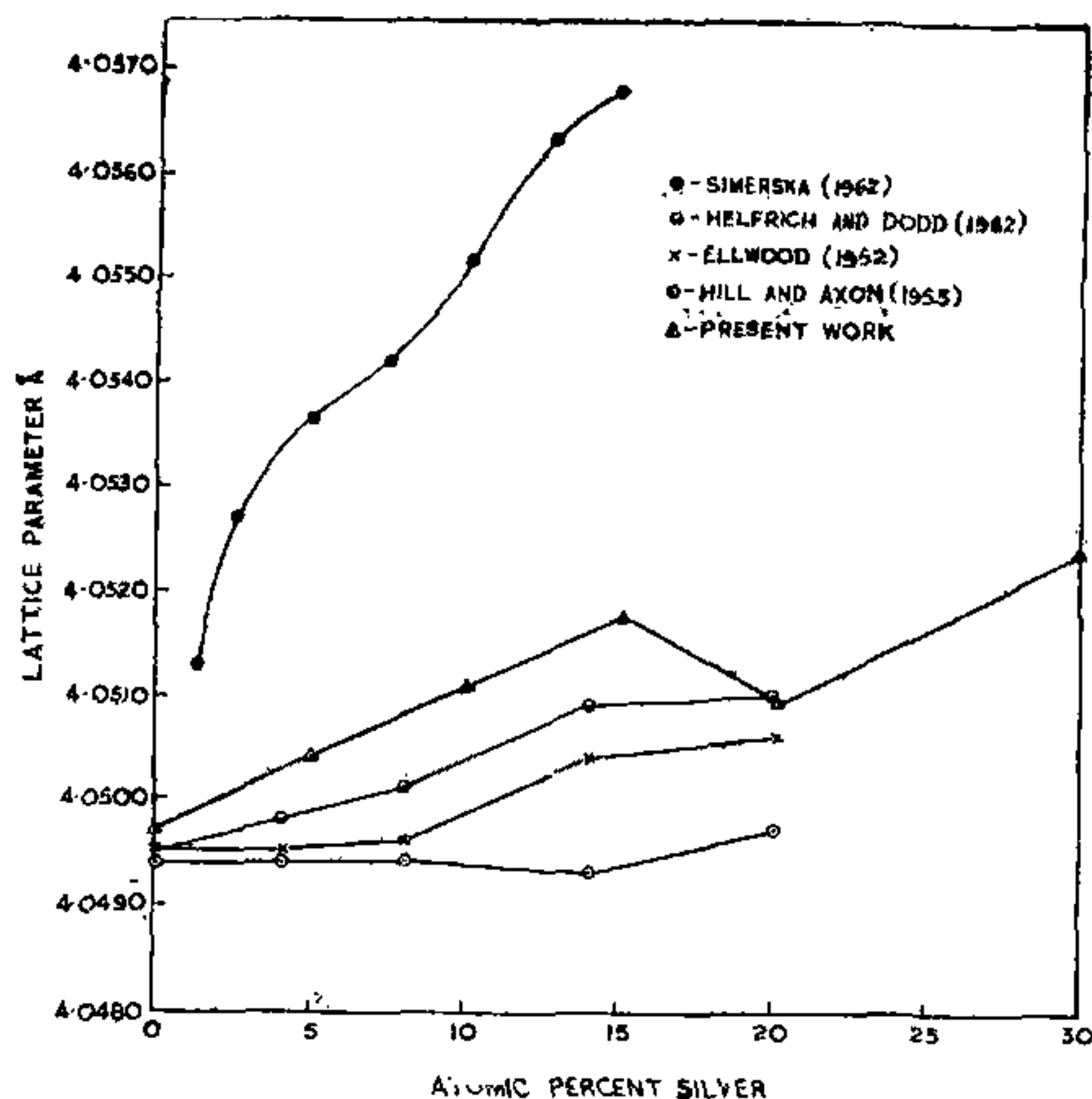


FIG. 2. Lattice parameters of aluminium-rich aluminium-silver solid solutions.

The X-ray diffraction data on lattice spacings of aluminium-silver solid solutions have recently been summarised by Pearson.¹⁰ According to Ellwood,¹¹ the lattice parameter remains unaltered upto 6 at.% silver and shows a rapid increase between 6 and 14 at.% silver. The results of Helfrich and Dodd¹² agree in form with those of Ellwood. Hill and Axon⁶ have reported an initial slight decrease in the lattice parameter. The high temperature data of Simerska¹³ when reduced to room temperature show an irregular and rapid increase in the lattice parameter with increasing additions of silver. Guljaev and Trusova¹⁴ have also reported a rapid increase. The lattice parameters determined in the present work from the (422) reflections of liquid-quenched aluminium-silver alloys show an increase upto about 30 at.% silver with an anomaly at 20 at.% silver. It is interesting to note that this anomaly corresponds to that observed in the solvus line¹⁶ in the aluminium-silver equilibrium diagram (Fig. 1). The sudden drop in the lattice parameter at 20 at.% silver as well as the anomaly in solid solution data is not readily understood and may be related to electronic effects and the formation of a defect structure. A similar trend in the variation of lattice parameter has been obtained in this investigation from a study of the (331) reflections also.

The structure of the ζ phase has been investigated earlier. The ζ phase has an h.c.p. structure and the lattice spacings are found to vary with composition. Westgren and Bradley¹⁶ found that the axial ratio (c/a) varies from 1.625 at 73 at.% silver to 1.588 at 57 at.% silver. Massalski and Cockayne¹⁷ have observed that the basal lattice spacing (a) varies linearly with the electron concentration per atom, but the curves for the 'c' spacing and the axial ratio show a distinct change of slope between the electron concentration values of 1.62 and 1.63. In the present investigation the axial ratio of the phase in an alloy having 65 at.% silver was measured both in the annealed state and after liquid quenching. In the annealed state the axial ratio was found to be 1.600 while it rose to 1.608 after liquid quenching. This increase suggests that the axial ratio may be a function of temperature in addition to its being composition-dependent. Further work is in progress to study the variation of axial ratio with temperature. It is interesting to note in this connection that the ζ phase precipitating from vapour-quenched aluminium-rich solid solutions also exhibits a decrease in axial ratio with ageing.⁹ A similar variation of axial ratio might occur in liquid-quenched alloys and needs further investigation.

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1. Pol Duwez and Willens, R. H., *Trans. Met. Soc., AIME*, 1963, **227**, 362.
2. Predecki, P., Mullendore, A. W. and Grant, N. J., *Ibid.*, 1965, **233**, 1581.
3. Anantharaman, T. R. and Ramachandra Rao, P., *Eastern Metals Review*, 1967, **19**, 141.
4. Pol Duwez, *Progress in Solid State Chemistry*, 1966, **3**, 377.
5. Hansen, M., *Constitution of Binary Alloys*, McGraw-Hill Book Company, Inc., New York, 1958.
6. Hill, R. B. and Axon, H. J., *Research*, 1955, **8**, 52.
7. Anantharaman, T. R. and Christian, J. W., *Brit. Jour. Appl. Phys.* 1953, **4**, 155.
8. Otte, H. M. and Esquivel, A. L., *Trans. Met. Soc., AIME*, 1965, **233**, 1276.
9. Fukano, Y. and Ogawa, S., *Acta Cryst.*, 1956, **9**, 971.
10. Pearson, W. B., *Handbook of the Lattice Spacings and Structure of Metals and Alloys*, Pergamon Press, New York, 1967.
11. Ellwood, E. C., *Jour. Inst. Metals*, 1952, **80**, 605.
12. Helfrich, W. J. and Dodd, R. A., *Trans. Met. Soc., AIME*, 1962, **224**, 757.
13. Simerska, M., *Czechosl. J. Phys.*, 1962, **12**, 54.
14. Guljaev, A. P. and Trusova, E. F., *Z. Tekh. Fiz., SSSR*, 1950, **20**, 66.
15. Raynor, G. V. and Wakeman, D. W., *Phil. Mag.*, 1949, **40**, 404.
16. Westgren, W. and Bradley, A. J., *Ibid.*, 1928, **6**, 280.
17. Massalski, T. B. and Cockayne, B., *Acta Met.*, 1959, **7**, 762.

SIGNIFICANCE OF FISSURES AND CRACKS DEVELOPED IN EARTHQUAKE AFFECTED AREA AROUND KOYANANAGAR, MAHARASHTRA

ANANT V. PHADKE

Department of Geology, University of Poona, Poona

INTRODUCTION

FIVE major earthquakes rocked the region around Koyananagar (17° 24' N : 73° 45' E—Approx.) within a period of four months and the shock of the 11th December, 1967 was the most severe (magnitude 7.5-Richter scale) and was felt all over the country. Some fore-shocks and hundreds of after-shocks which are still being received in the Koyananagar area, are recorded. According to the reports of the meteorological observatory, Poona, the epicentres of all these earthquakes were within an area of about 10 km. radius around Koyananagar where the hydraulic dam on river Koyana is situated. Geologically, the area in the region is occupied by the basic rocks of the Deccan Trap formation. Lateritic caps covering the hilly regions is a common feature and the soil in this area is also lateritic.

FISSURES AND CRACKS

Mainly two types of fissures and cracks were seen to have developed in this region after the earthquake of the 11th December 1967. The first type of fissures and gapings are developed in soil and on steep slopes of high hills and there is no doubt that these have been produced due to the slumping of soil and subsoil along the slopes. It was also recorded that some instances of land slides have taken place under such conditions and it is very remarkable that the majority of the land slides were observed in a zone trending N 20° E-S 20° W along Rundhiv-Lotiv, Kadoli, Donicha Wada, Nanel, Baje, etc. (see Map 1).

The second type of fissures, which were also seen to have developed in soil only, have altogether different characteristics. These cracks typically show a right handed en echelon