

abundant  $\text{CO}_2$  and some  $\text{H}_2\text{S}$ , issue at  $64^\circ\text{C}$  from a vein-system of gypsum seamed by stilbite. In both cases WEED relates deposition of the stilbite to the present as well as ancestral waters, but WHITE (1955) considers the evidence inconclusive.

SAKURAI and HAYASHI (1952) have described the silica-rich lime zeolite yugawaralite from andesitic tuff which has been much metamorphosed by hot-spring action about 300 miles from the present Yugawara hot spring, Japan. Coexisting minerals are quartz, and minor laumontite, chabazite and mordenite (ptilolite). Epistilbite, heulandite and stilbite are also reported (SAKURAI, 1953).

It is well known that chabazite, christianite (phillipsite), rarer mesotype (natrolite) and possibly other zeolites have been deposited in the wall-work of Roman baths at Plombières and elsewhere (DAUBRÉE, 1879) where hot spring water emerges at a maximum temperature of  $70^\circ\text{C}$ . The zeolites occur both within the pores of old tiles and in the mortar, and are accompanied by opal, chalcedony, plombierite, calcite and apophyllite.

### 3.3. Michigan copper deposits

BRODERICK (1929, 1931; esp. 1929, Figs. 4, 7, 8) has described a crude zoning related to depth in the copper-bearing amygdaloids of Keweenaw Point. Successive zones in downward order are characterized by zeolitization (with laumontite, analcime, natrolite, stilbite, datolite, apophyllite); prehnitization overlapping on to the zeolitization zone and characterized by abundant adularia as well as prehnite; and sericitization and propylitization in which sericite takes the place of adularia, and sulphides and ankerite are introduced. Persistent in all zones are epidote, pumpellyite, calcite, quartz, chlorite and native copper, and late veins and vug-fillings of laumontite, prehnite and datolite. Assemblages typical of the deeper, higher-temperature zones penetrate upwards in the neighbourhood of fissures suggesting invasion by heated solutions. Apart from the presence of such minerals as apophyllite, datolite, copper and sulphides, the zoning is broadly analogous to that of the greywackes and semischists of southern New Zealand, natrolite and thomsonite, which are rarer than laumontite and analcime (BUTLER and BURBANK, 1929), possibly being indicative of local silica-deficient conditions. The vesicles are considered by BUTLER and BURBANK to have been filled after accumulation and tilting of the whole lava sequence and overlying sedimentary formations.

### 3.4. Zeolites in amygdales, joints and other cavities

The larger part of zeolite literature refers to occurrences in amygdales and to fillings of other cavities, especially in igneous rocks. Yet such occurrences are particularly difficult to interpret from a physicochemical point of view. It has been customary for authors to publish paragenetic sequences based largely on textural considerations which are often questionable, and furthermore the sequences have often been pieced together from incomplete series in separate cavities (e.g. NIGGLI *et al.*, 1940, Fig. 242), a procedure of doubtful significance unless composition of the depositing solutions can be equated. An observed sequence of cavity fillings may be a function either of changing composition of the depositing solutions or of changing  $P$ - $T$  conditions, or both.