Euhedral chalcopyrite crystals displaying the sphenoidal form were studied from 15 different geologic environments. In every case the dominant sphenoidal faces were found to be Cu–Fe surfaces. This demonstrates that the anion direction $[\overline{1}\overline{1}\overline{2}]$ is the fast growing direction as opposed to the cation direction.

The polarity of chalcopyrite was further related to the polarity in sphalerite in cases where both minerals were found intergrown. In addition, the polarity effect on epitaxial growth of chalcopyrite on sphalerite was established.

Light-figure reflections obtained from mechanical etch pits developed in chalcopyrite were also used to establish new microcleavage planes in the mineral.

CRYSTAL–CHEMICAL CALCULATIONS

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Methods are indicated for calculating: (i) the stoichiometry of multicomponent isomorphic variants (e.g., complex silicate minerals), (ii) the number of oxygen atoms in the unit cell, (iii) the unit-cell dimension of a cubic isotope from several known members of the same series, and (iv) the unit-cell volume of a non-isometric substance from the volume of a single known isotype. Any physical characteristic that will lead to a calculation of the density can be used as a basis for calculating other scalar properties, such as the refractive index (for an isotropic substance). When the analogies are close, predictions are often within 2% of experimental results.

BIOMINERALOGY: ITS APPLICATIONS

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Because of the physiological significance of diseases, and growth and repair of bone among vertebrate animals, considerable attention has been given to the biomineralization process. This process, involving both biochemistry and inorganic crystal chemistry, can be studied among more primitive phyla (invertebrates) through application of electron microscopy and diffraction. In addition to the ordinary carbonate (calcite and aragonite) hard parts, biomineralization among marine organisms produces such insoluble substances as fluorite and quartz (as euhedral crystals), but may also include soluble intratissue substances, such as NaCl. Pathological biomineralizations include numerous substances, but straightforward relations between etiology and a precise knowledge of the biominerals will be difficult to establish. Although ingestion of fluorides is known to be related to susceptibility toward dental caries, for example, the relations between crystallochemical differences and resistance to disease are not known. It is possible, for example, that the amount of chemically bound water in the carbonate apatite of dental enamel may be one of the most significant factors affecting its "stability".

APPLICATION OF THERMOLUMINESCENCE TO GEOLOGICAL PROBLEMS

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The defect conditions in the crystal lattice of some rock-forming minerals reflects certain aspects of the geological history of the rock. By utilizing various sample treat-

ment techniques, the thermoluminescence response of these minerals can be employed to investigate a number of geological problems.

The phenomenon can be broadly subdivided into (1) radiation-induced thermoluminescence and (2) non-radiation induced thermoluminescence. With varying degrees of success, the first type of thermoluminescence has been utilized in the investigation of radiation-damage and radiation-dosimetry problems. Among the areas investigated have been:

(*a*) Geochronology of carbonates, fluorite, quartz, and feldspars in deformed and undeformed sedimentary rocks, meteorites, fluorite deposits, Recent lava flows, and ancient pottery.
(*b*) Stratigraphic correlation of carbonate rocks.
(*c*) Paleoclimates and deglaciation of carbonate rock areas.
(*d*) Geothermometry of dykes, carbonate minerals and meteorites.
(*e*) Studies of the radiation environment of meteorites and Recent shells.

The second type of thermoluminescence may be related to a number of possible causes including stress, trace elements, mineralogy, phase transformation, and adsorbed gases. In this area, investigations have included:

(*f*) Variation in remnant stress conditions in the vicinity of meteorite craters (carbonate rocks), nuclear explosions (halite), faults and deformed sedimentary rocks, and artificially deformed ice, carbonates, and feldspars.
(*g*) The distribution of (mainly) non-radiation induced thermoluminescence around certain hydrothermal and metasomatic ore deposits in both carbonate and feldsspathic rocks.

In addition, the phenomenon lends itself to a number of laboratory techniques including the evaluation of the radio-active content of weakly radioactive materials, gas adsorption phenomena and the distribution of calcite and dolomite in carbonate rocks.

Tracing of the movement of sediments in streams by making use of the strong thermoluminescent response of artificially irradiated quartz grains has been proposed.

THE ROLE OF EXCITED ELECTRONS IN "GROUND PREPARATION" FOR REPLACEMENT ORE DEPOSITS

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The localization of replacement ore mineralization can sometimes be ascribed to fold or fracture structures or pre-ore alteration, but in other cases the reasons for the emplacement of an orebody are more obscure. A possible basic cause for pre-ore alteration or ore-bearing solutions having reacted more readily with one portion of an apparently homogeneous rock unit may have been the presence of large numbers of lattice defects and excited state electrons in minerals of the country rock.

Lattice defects which are not directly due to initial crystallization may be caused by either ionizing radiation from radioactive materials, *or* unrelieved stress, *or* the introduction of trace elements into the lattice by metasomatic processes, *or* recrystallization due to heating by igneous intrusions. Both lattice defects and excited electrons may be generated by ionizing radiations, while other defect-forming mechanisms cause electrons to be raised from the ground state to an excited state in order to maintain electroneutrality in the crystal. Many such defects are metastable and tend to be destroyed (with a return of the electrons to the ground state) by either thermal annealing or chemical processes such as weathering or hydrothermal replacement.

Thermoluminescence studies in the vicinity of a number of replacement ore deposits suggest pre-ore "ground preparation" by unrelieved tectonic stresses or recrystallization. In theory, concentrations of low level radioactivity or "activating" trace elements should have the same effect. Identifiable thermal annealing effects are rare and most decreases in lattice defects and excited electrons appear to be due to chemical processes.