Recent Calcite-Cemented Sandstone Generated by the Equatorial Tree Iroko (Chlorophora Excelsa), Daloa, Ivory Coast

Carozzi, Albert V.

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RECENT CALCITE-CEMENTED SANDSTONE GENERATED BY THE EQUATORIAL TREE IROKO (CHLOROPHORA EXCELSA), DALOA, IVORY COAST[1]

ALBERT V. CAROZZI
University of Illinois, Urbana, Illinois

ABSTRACT

In the region of Daloa, Ivory Coast, several *Iroko* trees (*Chlorophora excelsa,* family of the Moraceae), a frequent species of the equatorial rain forest known for its calcareous excretions always related to wounds kept unhealed by insect activity, show an unusual lithogenetic aspect of this process.

Between severely damaged roots, large-scale bleeding of the sap, after unsuccessful attempts to build crusts of fibrous carbonate over the wounds, has penetrated into the interstitial spaces of the adjacent granitic residual sand and cemented it by precipitation of calcium carbonate into large blocks of hard and massive calcite-cemented pure-quartz sandstone. The quartz and rare feldspar grains displayed a high amount of marginal corrosion by the cryptocrystalline calcite cement.

The agents responsible for the severe damage to the trees cannot be determined with certainty but are assumed to be elephants, wild boars or jungle buffaloes. This recent sandstone demonstrates processes of intense corrosion of detrital quartz and feldspar grains and of general cementation both by calcite which have taken place at or near the surface before any decay, burial, overburden or compaction could occur and which, therefore, should be considered as geologically instantaneous.

INTRODUCTION

The region of Daloa in the Ivory Coast consists essentially of calco-alkaline granites (dated 1611–2028 MY) belonging to one of the rejuvenated median massifs of the Middle Precambrian Eburnean geosyncline which trends northeast to southwest across most of the country (Tagini, 1965). The extensively peneplained granitic terrane of the region reaches an elevation of 200 to 300 meters above sea-level and is entirely covered by a dense equatorial rain forest. The annual rate of precipitation is 1500 mm distributed in a major rainy season (March to June) and a minor one (September to November). The average temperature varies between 21° and 33°C.

GENERAL DESCRIPTION

The *Iroko* or *Chlorophora excelsa* (Benth. and Hook.f.), which belongs to the family of the Moraceae is one of the most frequent and valuable timber of the African equatorial forest from Sierra Leone to Tanzania. This wood is in great demand chiefly for its durability which includes resistance to termites and as a substitute for teak. The *Iroko*, although essentially a tree of the rain forest, extends also farther north into the drier savannah along stream galleries. It is a very tall tree with a cylindrical trunk (average diameter of 1.7 m) which often reaches a height of 30 meters before branches begin. The upper part of the tree has the shape of an inverted pyramid formed by a sheaf of large branches supporting very intricate and light sheets of extended foliage. The bark is thick and sclerosed, with a dark brown to blackish scaly surface displaying yellowish lenticels. There are no appreciable buttresses near the base of the trunk and the reddish roots are also covered with yellowish lenticels (Aubréville, 1959).

PREVIOUS WORK

The Moraceae are well known for their predisposition to siliceous and calcareous secretions. In the leaves, the cell walls are often silicified or calcified particularly in the hairs and epidermal tissues, but more deeply seated cells are also effected at times. Crystals either solitary or secreted in irregular clusters may fill whole lumen of small epidermal cells. In species of *Ficus* and *Chlorophora*, true cystoliths of calcite occur in the epidermis on one or both surfaces of the leaves and appreciably deform the shape of the cells, and in young stems the primary cortex may become extensively sclerosed and display a ring of stone cells (Metcalfe and Chalk, 1950).

However the most spectacular products of the Moraceae are the large deposits of calcium carbonate called "stones" frequently found in the wood of *Chlorophora excelsa*. These stony materials have aroused considerable interest both as unusual biological products and as commercial defects of the timber.

These accumulations of calcium carbonate oc-

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cur in three major types (Harris, 1933). In the first one, they appear as irregularly shaped masses, compact or porous which reach a maximum diameter of 15 to 20 cm. Their color ranges from white to dark brown with increasing content of impurities such as wood chips, decayed wood powder, soil particles and insect remains. The calcium carbonate content ranges between 62.5 to 78.8 percent. The "stones" belonging to this first group occur most commonly on the scar site of fallen branches, on the stem surface where the rind has been lost through fire or other damage, in the hollow centers of decayed stems (Campbell and Fisher, 1932), in the groove between two fused stems and quite frequently occluded inside the timber. However, in this last situation the stony mass was originally formed in an external position and subsequently enclosed.

The second type of carbonate accumulation consists of plugs of clean and hard material ($CaCO_3$ content 84.1%) filling the very large oval borings of cerambycid larvae. The third type forms thin scales of carbonate material ($CaCO_3$ content 61.2%) covering minor external wounds. These crusts are usually crumbly on the inside but display a shiny exterior surface.

In all described instances the formation of the calcium carbonate deposit results from an abnormal excretion of the tree directly related to wounding. Stems of *Chlorophora* may be wounded through the action of a number of agents depending on local conditions: direct cutting by man, barking of the lower parts of the trees by young elephants with their trunks, tearing of branches by storms, charring by seasonal fires. This last factor is well demonstrated by the abundance of stony accumulations in the savannah-grown *Chlorophora* (Harris, 1933).

Since the initial condition is a wounding of the tree which exposes the xylem and more particularly the cambium and neighboring tissues, it would seem logical to assume that the flow of sap containing the calcium bicarbonate which upon contact with the air precipitates as calcium carbonate should stop rather rapidly and effectively seal the wound. On the contrary, field observations and the relatively large size of the carbonate deposits indicate that sap exudation streams from the same wound are maintained for a period of years although they periodically undergo a certain reduction during the dry seasons when growth processes are slowed down. This almost continuous bleeding of the tree can only occur under the stimulus of insect activity (Harris, 1933). Indeed, insects which are not wood borers as well as others which are feeding on timber or boring in it are always present in great number around the wounds setting up conditions which strongly reduce and almost prevent healing for long periods of time. The remains of such insects are finally included in the carbonate deposits themselves together with other impurities.

INVESTIGATED EXAMPLES

In the region of Daloa (fig. 1), 32 km south of town and 17 km northeast of Issia, along a forestry trail of the lumber company S.E.F.I., in the Zuzua sector, several *Iroko* trees with roots and lower portions of trunks severely damaged, display an unusual and excessive capacity of secreting calcium carbonate. The product consists of irregularly shaped blocks, 1 to 1.5 m in size, of calcite-cemented pure-quartz sandstone caught between the roots or scattered on the ground in their immediate vicinity. This process of cementation of the residual granitic sand on which the trees are growing reaches the magnitude of a real lithogenesis and has never been described to our knowledge in spite of its obvious geological interest.

The calcite-cemented sandstone appears megascopically as a massive, extremely hard, tan to dark-yellow rock, with a resinous luster on fresh surfaces. It often contains debris of wood of variable size similar to those usually found on the ground between trees in a forest and remains of insects. Near the adjacent roots and lower part of the trunks, the sandstone becomes irregularly banded by zones of fibrous calcite which coat the wounds as superposed crusts.

Under the microscope, the rock is a grain-supported sandstone consisting almost exclu-

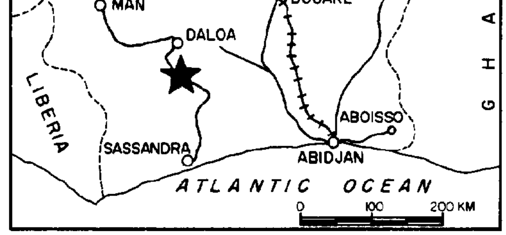

FIG. 1.—Location map. The star indicates the approximate position of the investigated *Iroko* trees.

sively of quartz grains of granitic and metamorphic origin. Rare grains of albite, microcline, tourmaline and a few muscovite flakes are also present. In this residual deposit which has the unique textural aspect of a completely unsorted sediment, the quartz grains reach a maximum size of 2.56 mm with an average of 1.10 mm (fig. 2). They are characterized by extremely irregular shapes although a few grains show parts of crystal faces. Most of the grains are single optical individuals and only a few are aggregates probably originating from vein quartz. Optical properties of the quartz are normal and undulose extinction rare.

The very irregular shape of the quartz and feldspar grains results from deep embayments accompanied by hazy boundaries produced by a well-developed marginal corrosion *in situ* by the calcite cement (fig. 3). The latter consists of an irregularly mottled and dark crypto to microcrystalline calcite containing abundant pigments of organic matter. X-ray diffraction analysis indicates pure calcite. Along the margins of the deeply corroded grains the calcite forms a coarser and clearer band consisting of a mosaic of anhedral grains reaching .021 to .030 mm in size (fig. 4). The width of this marginal band is directly proportional to the amount of corrosion. In large interstitial spaces, the dark cryptocrystalline calcite shows either a few well defined and large patches of the same coarser mosaic or an irregular sprinkling of smaller patches, both occurrences corresponding to completely replaced quartz grains (fig. 4). Intermediate situations also occur in which large areas of coarser mosaic contain irregular and minute fragments of quartz with same optical orientation representing the remains of a former single grain.

In the transitional zones between the blocks of massive sandstone and the adjacent roots, thick bands of fibrous calcite in which individual blades reach a length of .8 mm alternate irregularly with thin streaks of the above described sandstone or of dark cryptocrystalline calcite similar to its cement and containing a few minute and corroded grains of quartz (fig. 5). The bands of fibrous crusts eventually become the only deposit immediately adjacent to the wounded roots.

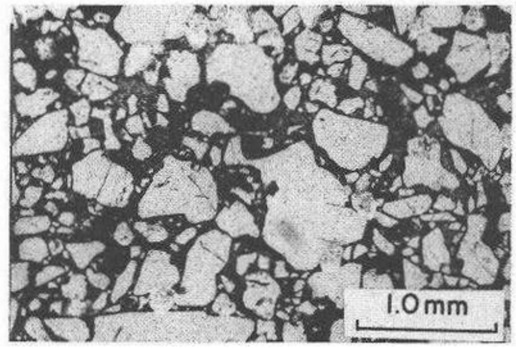

FIG. 3.—Calcite-cemented pure-quartz sandstone generated by *Iroko* trees. Notice deeply embayed quartz grains with hazy boundaries produced by intense marginal corrosion *in situ* by dark cryptocrystalline calcite cement. Nicols not crossed.

INTERPRETATION

The calcite-cemented sandstone just described which rests through fibrous carbonate crusts against severely wounded roots of *Iroko* trees has been generated by unusually large bleedings of the sap. The latter, after unsuccessful attempts to close the wounds by the development of crusts flowed into the interstitial spaces of the adjacent granitic residual sand and by precipi-

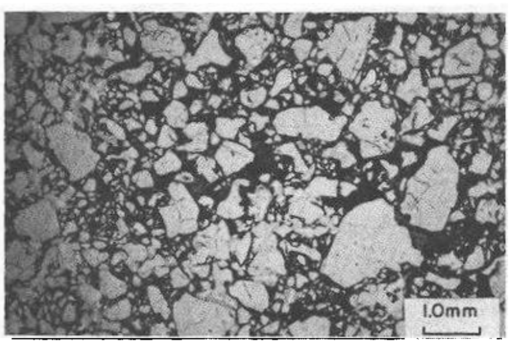

FIG. 2.—Calcite-cemented pure-quartz sandstone generated by *Iroko* trees. Notice complete absence of sorting in this residual granitic deposit and extremely irregular shape of the quartz grains set in dark cryptocrystalline calcite. Nicols not crossed.

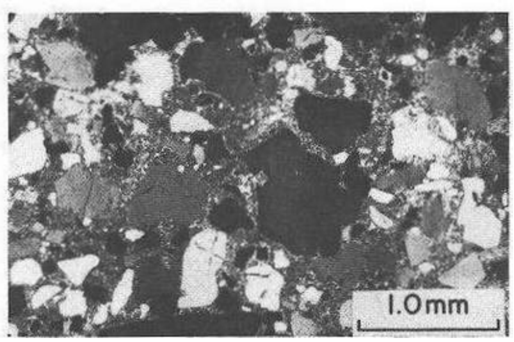

FIG. 4.—Calcite-cemented pure-quartz sandstone generated by *Iroko* trees. Notice the marginal bands of coarser calcite surrounding deeply corroded grains and numerous small quartz residues in large interstitial spaces corresponding to original grains almost completely replaced. Same as figure 3, nicols crossed.

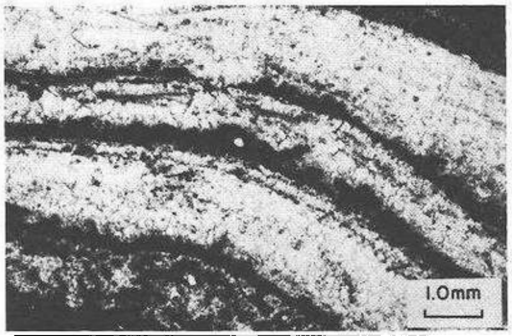

FIG. 5.—Crusts of fibrous calcite generated by *Iroko* trees. These thick irregular crusts alternate with thinner bands of dark cryptocrystalline calcite, similar to the cement of adjacent sandstone and containing a few corroded quartz grains. Such alternations usually separate the sandstone from the wounded roots of the trees. Nicols not crossed.

tating calcite converted it into hard sandstone.

This unusual production of bicarbonate-bearing sap might have been facilitated by the intense leaching to which the area is submitted. The superficial groundwater of the Daloa region contains an ample supply of minerals and, for instance, the average content of one hundred water samples is 30.7 mg of Ca^{++} and 108.7 mg of HCO^{-3} per liter, the pH being 6.5.

The agents responsible for the severe damage of the lower parts of the trunks and the roots of the investigated *Iroko* trees cannot be determined with certainty, but the destructive action of elephants, wild boars or jungle buffaloes seems the most plausible explanation for that particular area.

The described calcite-cemented sandstone demonstrates two processes which have taken place at or near the surface, without burial, overburden or compaction during a span of time of a few years and which therefore should be considered as geologically instantaneous. The first one is the intense marginal corrosion of the quartz and feldspar grains by the cryptocrystalline calcite cement. In the second, the cementation itself which has led to the perfect preservation of wood debris and insects. This latter process has some analogies with the genesis of coal balls in the Pennsylvanian swamps which have also perfectly preserved, in fibrous calcite, uncompacted plant debris containing even residues of protoplasmic substances inside cells (Schopf, 1961).

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