# Pearls as Biomineralization Models for Layered Growth and Crystallization

JEAN-PIERRE CUIF[1*], YANNICKE DAUPHIN[2], JULIUS NOUET[3]

[1] University Paris-Sud Orsay, Geology, jean-pierre.cuif@u-psud.fr
(* presenting author)
[2] University P. and M. Curie, Paris yannicke.dauphin @upmc.fr
[3] University Paris-Sud Orsay, Geology , julius.nouet@u-psud.fr

Cultivated pearls are produced by introducing a *graft* (a fragment of the mantle cut from the nacre producing area of the *Pinctada*) in the body of a "receiver" pearl oyster. The mineralizing side of the graft (the outer cell layer) is placed against the surface of a *nucleus* (a sphere of Ca-carbonate acting as substrate). After a recovery period during which the nucleus is completely wrapped by the graft spreading on the nucleus surface, resulting in formation of the *pearl-sac*, the mineralizing epithelium regains activity. But in contrast to what can be expected, minerals deposited by the newly formed tissue exhibit a great diversity in structures, correlated to an equivalent diversity in the associated biochemical compounds.

Taking advantage of an on-going research program (ADEQUA) granted by the Polynesian Office for Marine Resources, several tens of pearls grafted and grown in controlled similar conditions have been submitted to different physical methods allowing correlated mineralogical and biochemical data to be collected.

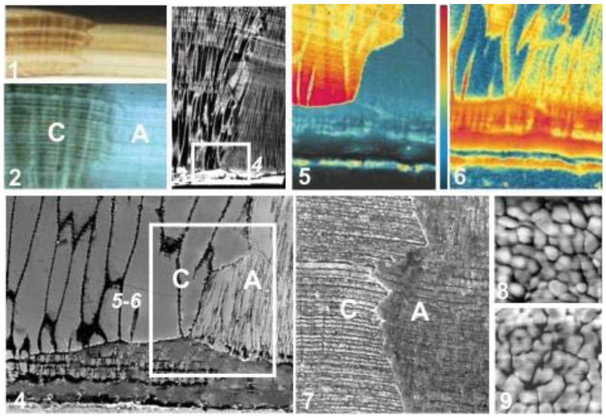

**Figure 1:** Example of a composite (calcite aragonite) pearl layer early developmental stage. 1: optical; 2: UV-fluo; 3: Laser conf.; 4: BSE; 5: XANES S-polysaccharides; 6: XANES S-protein; 7: SEM; 8-9: AFM.

Physical *in-situ* characterizations (Fig. 1) illustrate the strict correlation between organic secretions and mineralogical properties of distinct areas of the pearl bed [1]. AFM data show that whatever the biochemical composition of the organic phase, mineralized material exhibit a reticulate pattern without any crystalline growth faces. Extensive investigation [2] suggests that this layered mode of growth and crystallization is a widely shared process.

[1] Cuif *et al.* (2011) *Aquat. Liv. Res.* **24**, 411-424. [2] Cuif *et al.* (2011) Biominerals and Fossils through Time. Cambridge Univ. Press, 490 pp.

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# Durability of the Uranium resources

MICHEL CUNEY

UMR7566-CNRS CREGU-Université de Lorraine, FRANCE
michel.cuney@g2r.hup-nancy.fr

## Introduction

Uranium is a major mineral resource for the production of energy. Primary resources (conventional and unconventional) derived from mining, can be supplemented by secondary resources [1]. However, only a small fraction of the U from the primary resources is presently used in nuclear reactors and a small part of the various materials issued from nuclear fuel cycle (secondary resources) are reprocessed to be re-used as a nuclear fuel.

## Conventional uranium Resources

U deposit types are extremely diverse and form at all steps of the geological cycle [2], but three types: Olympic Dam, diagenetic-hydrothermal and deposits related to meteoric water infiltration represent over 75% of identified world U resources [3]. Identified resources recoverable at less than $260US /kg U ($118US/pd) reach 6.306 Mt U [1], and can last for 100 years at the present rate of consumption by the nuclear reactors.

## Unconventional uranium Resources

The durability of the U resources can be greatly increased by the recovery of U as minor by-product of the mining of phosphorites, carbonatites, black shales, lignite, seawater. A variety of other non-conventional U resources are being or may be developed in a near future: production from the cleaning of waters deriving from former U mines and tailings, reprocessing of tailings produced by previous U or other metal extraction, recovery from Ni-Zn black shale ores by bio-heapleaching (Talvivaara, Finland), recovery from lignite-coal ash, from porphyry copper operations, from monazite of sand placers if REE recovery from this resource restart.

## Secondary uranium Resources

The durability of the U resources can be further increased by developing the use of secondary resources. Only $^{235}$U (1/140 of the natural U) is burned in most nuclear reactors. In fact, 0.25 to 0.30% $^{235}$U remains in depleted U after enrichment, and 0.8 to1% remains in the spent nuclear fuel. The production of 1 t U enriched at 3.5% $^{235}$U leaves 6.7 t of depleted U. Burning of $^{235}$U produces a series of nuclides, among which about 1% of $^{238}$U is transformed to $^{239}$Pu, with a world production of 70t Pu /year (www.worldnuclear.org). Several processes have been or are being developed for a sustainable use of these secondary resources: dilution of military highly enriched U (HEU), re-enrichment of depleted U or spent fuel after preprocessing, use of Pu for MOX production, the burning of $^{238}$U with Pu or HEU in the 4th generation reactors increasing about 60 times the durability of the U resources.

## Conclusion

Beside conventional U resources large amounts of nuclear fuel can be recovered from unconventional and secondary resources. A sustainable development of nuclear energy requires a wider development of existing technologies and the development of new ones to use more thoroughly these differents types of U resources.

[1] IAEA (2009) Uranium 2009, Paris, [2] Cuney (2009) *Mineral. Dep.* **44**, 3-9, [3] Cuney (2012) *in Non-renewable resources Geoscientific & Societal Challenges, Springer*.