Impact of mining on aquatic systems: Lessons from Sardinian surveys

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Abandoned mine sites pose environmental hazards and risk to the human health. Mining in Sardinia (Italy) dates back to pre-Roman times. Base-metal ore exploitation and processing lasted several centuries, ended in 1980-1997, and left 169 abandoned mines, $71*10^6$ m^3 of residues (50% flotation tailings and slag that show high reactivity) spread over a 19 km^2 surface (RAS, 2003. Piano regionale di gestione dei rifiuti - Piano di bonifica siti inquinati. Regione Autonoma della Sardegna. 255 pp, in Italian). Most of these mines lay with non-identifiable responsability and this has led to non-action after their closure. Only recently the Regional Government has recognized the need of actions for reducing the environmental risks.

Hydrogeochemical surveys carried out since 1996 comprised about 200 sampling sites located in mined areas. Results of these surveys showed the outflows from flooded mines and drainages from mining wastes to be the main sources of contamination to the aquatic and soil systems. Relevant contaminants are Zn, Cd, Pb, As and Sb, depending on the composition of ore deposits at specific sites. Repeated sampling under different seasonal conditions showed that the mining residues release high concentrations of contaminants to surface waters; extreme contamination has been observed after storm events. The contamination level at some streams is high even during drought periods because they are only supplied by hyghly polluted mine drainages. The risk to human health is enhanced by the proximity of abandoned mines to water resources and cultivated land. Taking into account the results of geochemical and mineralogical studies, different actions are proposed for specific sites. These can be summarized as follows: 1) stabilization of the impoundments and waste piles (allowing low rates of erosion processes); 2) runoff diverting and drain systems at the waste dumps (minimizing contact between water and polluted materials); 3) treatment of mine drainage before discharge into streams (reducing downstream dispersion); 4) construction of artificial ponds and/or wetland (favoring precipitation and/or sorption processes); 5) treatment and/or removal of those materials highly contaminated.

Lessons lernt by past mining in Sardinia indicate that a correct disposal and management of the mining residues should be mandatory at the active mines. This would allow to reduce the environmental risks and the cost of rehabilitation.

Reconciling models of the solar nebula with the chondritic record

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Protoplanetary disks are dynamic objects, through which mass and angular momentum are transported; the net motions are inward, with much of the disk mass accreted by the central stars during their final stages of pre-main sequence growth. During this evolution, a disk is heated by dissipation effects within the gas as it loses mass and grows in its radius to conserve angular momentum.

Chondritic meteorites record a dynamic history of our own solar nebula, as they contain materials that formed in a variety of chemical and physical environments. Specifically, the refractory CAIs are the oldest objects in these meteorites and appear to have formed in a gas of solar composition, whereas chondrules, which also formed under high temperatures, were exposed to a gas with a range of oxidizing conditions and are enriched in heavy oxygen isotopes relative to CAIs. Further, within chondrite matrix are pre-solar grains, which had to escape high temperatures altogether. Despite these different histories, these materials were mixed together such that they are located within centimeters of one another on chondritic meteorite parent bodies.

To date, it is unclear how the dynamic evolution of a protoplanetary disk would give rise to the different environments sampled by chondritic meteorites and their components. However, recent work has shown that many of the general properties of chondritic materials can be explained within the context of an evolving solar nebula. For example, the high temperatures needed to form CAIs would be prevalent during the earliest, most rapid stages of nebular evolution. The dynamic environment that would be created at such a time would result in the large-scale redistribution of CAIs, allowing them to be transported outwards tens of AU. Declining mass accretion rates through the disk would prevent the CAIs from forming at later times, and would also allow those that were scattered outward to drift inward at rates that depended on their size. During this time, the properties of the inner solar nebula would have evolved, allowing the conditions needed to form chondrules to have developed [1]. Similar evolution is seen in disks around other stars [2]. Further development of these nebular models may provide a context within which to understand the formation of our solar system.

[1] Ciesla & Cuzzi (2006) *Icarus* **181**,178-204. [2] Carr & Najita (2008) *Science* **319**,1504-1507.