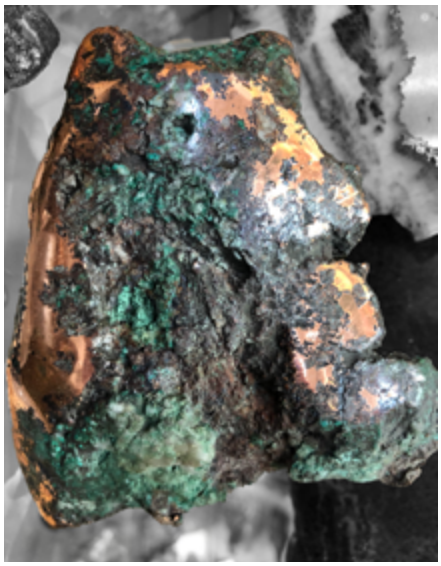
COPPER

Exploration, Mining, Refining, Characterisation



ALS has decades of experience with some of the world's largest copper projects. We have a range of methods to suit any project or deposit type from exploration to resource definition, and through to processing.

Historically, copper exploration with soil, rock and drill core samples has involved a simple aqua regia digestion and AAS, ICP-AES or ICP-MS analysis. Aqua regia easily decomposes common copper-bearing sulphide minerals such as chalcopyrite and bornite, as well as secondary copper minerals often found in association such as malachite, azurite and cuprite. Sediment-hosted Cu, redbeds, and IOCG deposits can be effectively explored using aqua regia digestion.

However, there is increasing recognition in the industry that exploration for porphyries may benefit from four-acid digestion. Copper porphyries with accessory molybdenum require a four-acid digestion for complete recovery. Secondary silicate minerals like chrysocolla show higher Cu recovery in a four-acid digestion. An added advantage of four-acid analyses is that routine use will produce a database of multi-element geochemistry which can prove to be exceptionally valuable in alteration and lithology mapping, especially when combined with a sub-set of XRF whole rock geochemistry results. Imagine having your entire geochemical library as a basis for an alteration index instead of inconsistent and tenuous results from a handful of drill core samples. Four-acid digestion analyses can also deliver insight into the ore minerals present in your samples, and aid in the understanding of magmatic processes.

Four-acid digestion is generally required for massive sulphide deposits due to the presence of refractory minerals incorporating metals such as nickel, cobalt, lead and zinc. Some sample matrices with very high sulphide content may require an oxidising fusion to overcome matrix effects inherent to acid digestion.

Instrument choice depends on the stage of your project and your goals as different detection limits are available from each. Greenfields exploration using trace element pathfinders require the sensitivity and range of the ICP-MS. Economical packages available from ICP-AES are suitable for ore body drilling with a trace element profile. For more mineralised samples, such as massive sulphide ores, ICP-AES analysis is ideal. The table below describes the most common methods used in copper exploration available at ALS Geochemistry. Please contact our client services team for alternatives.

	Aqua regia Methods	Four-acid Methods	Fusion Methods
Super trace Level	ME-MS41L™ 53 elements 0.01 ppm - 1% Cu	ME-MS61L™ 48 elements 0.02 ppm - 1% Cu	-
Trace Level	ME-MS41™ 51 elements 0.2 ppm - 1% Cu	ME-MS61™ 48 elements 0.2 ppm - 1% Cu	-
Intermediate grade	ME-ICP41 36 elements 1 ppm - 1% Cu	ME-ICP61 34 elements 1 ppm - 1% Cu	-
Mineralised	ME-ICP41a 34 elements 5 ppm - 5% Cu	ME-ICP61a 33 elements 10 ppm - 10% Cu	ME-ICP81 16 elements 20 ppm - 30% Cu

Copper Ore Mineral Characterisation

Mineral-selective leaches for copper can be useful at many different stages in a project's life. Some understanding of the recovery from common processing methods may be valuable during resource evaluation. Established mines may want to produce early metallurgical characterisation with exploration geochemistry during resource extension or infill drilling.

ALS Geochemistry offers a variety of processing methods for rapid, economical tests on standard pulp samples. Variations in acid strength, temperature, and leach time can be incorporated into these procedures, and they can be combined with sequential leaches for ore characterisation. We're happy to work with you on customising tests to the particular mineralogy and extraction method of choice for your project.

As well, leaches are available as sequential packages. Contact client services staff for more details.

Leach Type	Method	Description
Citric acid	Cu-AA04	Targets oxide/non-sulphide minerals. Used in heap leach and bioleaching.
Sulphuric acid	Cu-AA05	Targets oxide/non-sulphide minerals. Widely used in copper processing.
Cyanide leach	Cu-AA17	Targets secondary sulphide minerals and some primary sulphides Useful when the project contains gold.
Others	Cu-AA07n Cu-AA08q Cu-PKG06Li	Specialty leaches including water, ammonium acetate, and modified four-acid (perchloric acid replaced with sulphuric acid) are available. Sequential Leach Package.

Assaying copper products

ALS Geochemistry copper assays and related methods cover everything from overlimits on exploration samples to trace components in copper anodes. To develop the best analytical program for your ore grade samples, mill concentrates, or other specialised material, please contact Client Services to discuss your needs.

Sample type	Method	Cu Range	Description
Ore Grade Samples	Cu-OG46/OG62 Cu-AA46/AA62	0.001-50%. 0.001-50%	High grade copper ore assays with ICP-AES or AAS finish.
Native Copper	Cu-SCR21	0.01-100%	Metallic screen method for samples containing native Cu.
Copper Concentrates	ME-MS41c/MS61c ME-XRF15c Cu-VOL61	2ppm-10% 0.01-50% 0.01-100%	Cu concentrate methods by various decompositions - aqua regia, four acid, lithium borate Umpire assays are also available.
Specialty Products	Please inquire at your nearest ALS Geochemistry branch.		A variety of highly specialised determinations for Cu cathode, Cu anode, various plant solutions.

*Methods '41/46' are digested via Aqua Regia and '61/62' are digested via 4 acid.

ALS provides a wide range of specialised testing services covering all stages of your project's life cycle. Please visit alsglobal.com for more information on our services and specialties.

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