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Zircon ages, mineral zonings and geochemistry of Mg-skarn (containing nephrite) deposits along West Kunlun, Xinjiang, northwest China

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In the Western Kunlun Mountain, more than thirteen Mg-skarn deposits (containing nephrite) are distributed with the range of 1300km, which is also regarded as the longest one in the world. Also, the most highly placer valued nephrite deposits occur in the Yurungkash and Karakash Rivers in Hetian and primary nephrite deposits are found in Yutian, Yecheng, Qiemo and Ruoqiang, Xinjiang, Northwest China. However, the ages of these deposits and the geological environment in which they formed are not known, and their genesis, mineral zonings and their compositions, and geochemical and petrographic characteristics are poorly constrained. More than 150 samples of white, green, brown, and black nephrite were examined from the placers with the aim of understanding the timing and processes of formation of the nephrite and its archeological significance. Totally, white, green, black, brown nephrite were found due to the various contents of Fe, $Fe(OH)_3$, graphite and oxide irons as mineral inclusions in nephrite with zircon, titanite, apatite, spinel, garnet, epidote, barite, actinolite, sphalerite, pyrrhotite, graphite, calcite, and iron-hydroxide as associated minerals. The presence of strong negative Eu anomalies (0.04–0.26), flat REE patterns for most nephrite samples, and $\delta^{18}O$ = 1.3‰–8.4‰ (330°C) and δD = -17.7‰ to -87.1‰ (350–650°C) for the ore-forming fluids suggest the deposit is a Mg-skarn formed by the metasomatism of dolomite by fluids derived from local granite/granodiorite intrusions.

Particularly, lots of zircons were found in nephrite from nearly all the Mg-skarn deposits along the Western Kunlun Mountain. Zircons inclusions in the placer nephrite are oval in shape, < 200 mm long and < 100 mm wide. Their geochemical characteristics are typical of magmatic zircons, with high Th/U ratios (> 0.1), positive Ce anomalies (Ce/Ce*) of ≥ 1.31. All these zircons have similar geochemical signatures, suggesting they were derived from the magmatic rocks that host the nephrite deposits. Zircon grains from some nephrite yield ages of 389 ± 4 Ma, 397.1 ± 3.5 Ma, 440.7 ± 4.4 Ma or 377.8 ± 6.2 Ma. Other nephrite deposits also have the similar ages except Ruoqiang nephrite with ages of about 200Ma. These ages are roughly close to those of the emplacement age of their host granodiorites and probably represent the recrystallization of zircons or formation ages of the nephrite within the belt.

Mg-skarns that host the nephrite have been thermally metamorphosed. The first step in the formation of nephrite was alteration of the Mg-dolomite to form an assemblage of diopside, epidote, and minor grossular. This was followed by metasomatism of the skarn assemblage by pneumatolitic/hydrothermal fluids derived from local granitoid intrusions, which, combined with later brittle deformation, formed the fine-grained tremolite (nephrite). The placer nephrite contains more complex phases or associated minerals than does the primary nephrite. Primary nephrite is generally regarded as the main source of the downstream placer nephrite deposits. The fine grain-size of the tremolite and small quantities of accessory minerals are the main characteristics of high-quality placer nephrite.