

## APPENDIX 2

### Detailed descriptions of the possible source regions in the Swiss Alps and in the Bohemian Massif [in square brackets: short description of the once (bulk-rock chemically) measured "nephrite" sample from the given site]

#### THE SWISS ALPS

In Switzerland not only S-type nephrites but also D-type nephrites occur, e.g., in Scortaseo (Puschlav/Poschiavo), the largest outcrop of nephrite. The nephrite of Scortaseo occurs in a calcitic matrix at the contact of talc schist and dolomite marble and can be characterized as follows: pea-sized (4–8 mm); its colour is white or extremely light green; it appears in the shape of nodules whose weathered surface can have a red hue (Dietrich and de Quervain, 1968; Giess, 2003). [Comparative samples of D-type nephrite from Scortaseo (green, black and light green varieties) (Dietrich and de Quervain, 1968)]

S-type nephrites can be found in several localities in the Swiss Alps:

##### Puschlav/Poschiavo:

– Above Alpe d'Ur: compact-fabric, green nephrite in serpentinite near a large talc site (Dietrich and de Quervain, 1968). This talc site is near the above mentioned Scortaseo (where D-type nephrite occurs), although nephrite originating from this place (Alpe d'Ur) is S-type (Fig. 5). [Compact-fabric, green nephrite (Staub, 1917; Dietrich and de Quervain, 1968)]

– Below Piatte di Canciano (2250 ms a.s.l.): here nephrite occurs together with tremolite-asbestos in serpentinite, in a vein with a chrysotile-asbestine margin adjoining actinolite hornfels ("fine fibrous greenish hornblende"). The nephrite is greyish-green, foliated, asbestiform (Schmidt, 1917; Dietrich and de Quervain, 1968). [Compact-fabric, green, grey, "nodular", fibrous and asbestiform nephrite-varieties; (Schmidt, 1917; Dietrich and de Quervain, 1968)]

##### Val Malenco:

– Fuorcla Fellaria: actinolite-schist at the contact of serpentinite and biotite gneiss (Dietrich and de Quervain, 1968).

##### Oberengadin:

– Furtshellas im Oberengadin: compact-fabric, dark green nephrite variety in serpentinite, in the form of lens(es), lodes and veins; formation by transformation of actinolite schist (Staub, 1915; Dietrich and de Quervain, 1968). [Compact-fabric, green nephrite (Staub, 1915; Dietrich and de Quervain, 1968)]

##### Oberhalbstein (Alpi di Platta):

– South of Cuolms, in a watercourse: dark green, compact-fabric nephrite, occurs as lenses in serpentinite. At the contact of the nephrite and the serpentinite green talc-schist can be found (finely imbricated green talc with spinel relicts and titanite). Microscopical examination of the nephrite shows only scattered, sporadic, isolated magnetite grains and no other enclosed minerals (Dietrich and de Quervain, 1968). [Compact-fabric, green actinolite-nephrite (Dietrich and de Quervain, 1968)]

– South of Fuorcla da Faller: blackish-greenish, weathered and slaty nephrite, talc-schist and grey calc-phyllite attached to a tectonised coarse-grained diallage-gabbro (Dietrich and de Quervain, 1968).

– Fuorcla an der Muntognas digls Lajets: dark green nephrite: appears in strongly tectonised serpentinite, in the form of thin stripes and lenses. It is typical actinolite-nephrite (Dietrich and de Quervain, 1968). [Compact-fabric, green actinolite-nephrite (Dietrich and de Quervain, 1968)]

– Ruine Marmorera: green, compact fabric nephrite appearing with talc-schist (20–30 cm wide stripe at the contact of pillow-lava and serpentinite; Dietrich and de Quervain, 1968).

– Faller Valley (Val da Faller, Val Faller): in the valley there are several places where nephrite can be found on the surface: in the cut near the village of Mühlen (Mulegns) (Welter, 1911a; Dietrich and de Quervain, 1968; Giess, 2003) and at the foot of the Forschella-peak (Welter, 1911a; Dietrich and de Quervain, 1968).

In the cut near Mühlen there are serpentinite and spilite bodies with grey, green and red knotted slates at their contact. The nephrite body is between the serpentinite and the spilite; it was observed – in 1908 – in a belt (1 m wide and 4 m long), its estimated volume was then 20 m<sup>3</sup> (Welter, 1911a). In 1972 on account of the widening of the road the majority of the nephrite body was exploited, but its remains could still be seen on the surface in 2003 (Giess, 2003).

In the 2 cm wide intermediate zone (rich in epidote) between here and their foliated spilite and nephrite, very few calcite can also be observed. The groundmass of the spilite consists of feldspar, epidote, augite and chlorite; the augite-phenocrysts are uralitised, on their margins actinolite formed. Picotite (chrome spinel) and garnet are absent but magnetite and leucoxene appear in the spilite. Olivine, diallage and augite are common in the serpentinite. There is no sharp boundary between the serpentinite and the nephrite, the transition being gradual. The main component of nephrite is actinolite, appearing in parallel bundles, but the nephrite is rich in chlorite. Magnetite, picotite and green Ca-Al-garnet are also observable (Welter, 1911a; Dietrich and de Quervain, 1968).

The Faller Valley nephrite – when macroscopically examined – is particularly varied: dark green, foliated, fibrous-thread-like; then very light green, almost white, parallel-fibrous; and spring-onion green to pistachio-green, extremely foliated rocks with lamellar jointing alternate. The latter type is characteristic of the foot of the Forschella-peak (Welter, 1911a; Dietrich and de Quervain, 1968). In 2003 all types were visible in the Mühlen cut: mountain leather made up of white tremolite-fibres; red and green schists at the contact of the serpentinite; extremely foliated green nephrite; white weathered nephrite and the green foliated variety occurs beneath the weathered (white) rock bands (Giess, 2003).

At Sblocs – above Mühlen – strongly foliated, whitish-green nephrite can be found in serpentinite (Dietrich and de Quervain, 1968).

[Mühlen/Mulegns: foliated, dark green nephrite (Welter, 1911a).

Forschella: extremely foliated nephrite (Welter, 1911b).

Without exact locality (Val da Faller): “nephrite” (Welter, 1911a)]

– Near Salux (Salouf) the serpentinite is bound to gabbro, green and red knotted schist is formed at their contact zone. The nephrite-block first explored in modern times (1908) was 50 x 30 x 20 cms in size, dark green, definitely foliated and very tough (Welter, 1911a). Microscopic examination shows a very typical nephrite fabric: this consists of parallel fibrous minerals. It is very poor in enclosed minerals: yellowish-green garnet, brown spinel (picotite), isolated magnetite patches and some chlorite appear along the cleavage planes (Welter, 1911a). Yellowish-green garnet was also observed in nephrites found at Lake Boden (Kalkowsky, 1906; Welter, 1911a). [Compact-fabric, dark green nephrite (Welter, 1911a)]

– South of Crap Farreras: dark green, compact-fabric nephrite bound to a 20 cm serpentine band in diabase; its core is perfectly pure; few carbonate, some spinel-grains and some chlorite-patches present at its edge (Dietrich and de Quervain, 1968).

Dietrich and de Quervain in their comprehensive work (Dietrich and de Quervain, 1968) published some other occurrences, without detailed description or analytical data: one km west of Cima Val Fontana (the enclosing rock is dolomite-marble as in Scortaseo, so probably D-type nephrite occurs here); Lago di Cavlocc; South of Fuorcla da la Vallette; Piz Martegnas (nephrite in serpentinite).

Dietrich and de Quervain in their comprehensive work (Dietrich and de Quervain, 1968) published data without detailed – occasionally without any – description of some other provenances: Robenhausen (Pfäffikersee) (Heierli, 1902); Gotthardtunnel: [yellowish-green nephrite] (Heierli, 1902; Schneider, 1912); Gotthard (Heierli, 1902; Schneider, 1912); Andermatt 25: [nephrite and actinolite, greyish-green] (Schneider, 1912); Haudères (Val d'Hérens): [compact-fabric, greyish-green nephrite] (Preiswerk, 1926); Neuenburgersee (Lake Neuchâtel): [dark green-black nephrite-gravel] (Meyer, 1884).

## THE BOUNDARIES OF THE BOHEMIAN MASSIF

– Schwarzenbach an der Saale, in the western part of the Bohemian Massif, near the German–Czech border, in the Frankenwald Valley in Bavaria; north of the Münchberg gneiss-massif chlorite schist, serpentinite and saussuritised gabbro crop out. Near Schwarzenbach an der Saale, in the chlorite schist, a large-size lens-like serpentinite can be seen, it contains a considerable amount of nephrite. The serpentinite is very pure antigorite altered from pyroxene; its texture is extremely even (Welter, 1911a).

In this area, nephrite is difficult to recognize, weathering on the surface being so advanced that samples taken from the weathering crust can be scratched with a knife. The softened, weathered material is totally white, asbestine, friable. Nevertheless, in the central part of larger blocks fresh, typical green nephrite can still be found (Welter, 1911a). Microscopical examination of the nephrite shows “typical actinolite structure” with “general nephrite-structure”, that is the actinolite-fibres often become arranged in ripples, curls and knots. A specific feature of this nephrite is the appearance of hornblende with green – light brown and green – colourless pleochroism. Similar hornblende appears in the saussuritised gabbro as an alteration product of diallage. Chlorite, magnetite and leucoxene are also frequent in the rock (Welter, 1911a). [Green nephrite (Welter, 1911a)]

– In the northeastern part of the Bohemian Massif – in Polish Lower Silesia – 30 kms south of Wrocław, Jordanów (former “Jordansmühl in Schlesien”): in the village quarry serpentinite (Sudetic Ophiolite Suite, Central Sudetic Ophiolite, Ślęza Mt. Ophiolite Group; Mazur et al., 2006) crops out at the northern border of the Góry Sowie gneiss block (Gunia, 2000). In the mine, dark green or grey antigorite-serpentinite is the dominant rock-type; it is broken through by white or creamy, fine-grained rodingite-, plagiogranite – and quartz-zoisite – rock veins (Sachs, 1902; Gunia, 2000). Dyke thickness is usually from 0.5 to 2 m, although in the past veins with thicknesses of up to 3 m were reported (Sachs, 1902). Around the plagiogranite veins, a metasomatic contact zone is formed (with belts of quartz-zoisite, quartz-zoisite-tremolite, talc-schist and talc-chlorite-schist – outside the plagiogranite veins, towards the serpentinite). At the contact of rodingite veins, a metasomatic zone – the so-called black-wall – is

present. The black-wall is composed of chlorite schist, the thickness of which is from a few cm up to 1 m; metasomatic zones host irregular bodies, veins and “pockets” of nephrite (Gil, 2013). The size of the “pockets” does not exceed 40 cm, the thickness of the veins is 40 cm at most, while their length might exceed 2.5 m (Gunia, 2000). Nowadays, exposed nephrite bodies are from a few to ca. 50 cm thick. However, in the past, bodies with lengths of ca. 1.5 and ca. 0.5 m thick were obtained, their weight exceeding 2 tons (cf. Gil, 2013).

The most common nephrite and nephrite schist varieties reveal typical, non-directional fabric, also foliation or schistosity, and are composed predominantly of tremolite with Si apfu (atoms per formula unit) from 7.7 to 8.0, while diopside and chlorite are also common, and grossular, hydrogrossular, prehnite, antigorite, opaque Cr-spinel, titanite, apatite, monazite and zircon were recognized (Gil, 2013). The nephrite is green, varying from greenish-creamy and bright green, up to dark green.

In the past, the following nephrite varieties were described. The colour ranged from dark green to white with minute black patches on the surface of every varieties (Traube, 1885a; Gunia, 2000): dark green – nephrite bound to “granulite” (Traube, 1885a); light green – “pyroxene-amphibole rock” formed in serpentinite, and in it the former pyroxenes, later altered into amphibole, can be no longer recognized (Traube, 1885a). Greyish-blue, pink and bluish varieties were also reported (Gunia, 2000). Foliated, schistose and compact fabrics occur equally. In serpentinite-bound nephrite pseudomorphs after pyroxene (minute, parallel magnetite laths) occur but they are missing at many places. The fibrous amphibole crystals are often arranged in parallel fibre-clusters, on the top of the clusters the fibres open into a fishtail structure; otherwhere the amphibole-fibres are swaying elsewhere they might form a fan-shape or entanglement. Sometimes the amphibole threads enwrap squat grains (Traube, 1885a).

[Pale light green nephrite (“pyroxene-amphibole rock”: I.); dark green, compact-fabric nephrite with pseudomorphs after pyroxene (minute, parallel arranged magnetite-laces) (“pyroxene-nephrite bound to granulite”: II.); white, tremolite-nephrite (“primer-nephrite”: III.) (Traube, 1885a, b); dark green nephrite (see Fig. 7A: PGAA)]

– Złoty Stok (former Reichenstein in Schlesien): an abandoned gold and arsenic underground mine located about 30 km south from Jordanów, at the contact of the Kłodzko–Złoty Stok Granite with the Skrzynka Shear Zone (Gil, 2013). Within the Skrzynka Shear Zone, there are small serpentinite, pyroxenite (perhaps related to the Sudetic Ophiolite Suite, Central Sudetic Ophiolite) and marble bodies. In the 1880s to early 1900s, nephrite was described from the wall of the Książęca Gallery (former Fürstenstollen), forming layers at the contact of pyroxenite and serpentinite, although nowadays the mine gallery is partly collapsed, making sampling directly from the wall impossible (cf. Gil, 2013). However, nephrite blocks can be found in vicinity of the Książęca Gallery and in several mine dumps, and also in a more distant, western mine field.

At Złoty Stok, the pyroxenite is composed of diopside, tremolite-actinolite amphiboles, chlorite and löllingite. Diopside – its colour ranging from greyish-green to greenish-white – is often coarsely fibrous in fabric, including crystals several cm across. The rock is extremely fine-grained at places, its fabric is compact, its mineral composition can barely be recognized macroscopically: in the fibrous-thread-like rock diopside often alters into coarsely fibrous, light greenish tremolite or into “fibrous-thread-like hornblende”.

The most common nephrite blocks in Złoty Stok area are bright to dark green and greyish green, locally with reddish weathering zones; the fabric is typically non-directional or layered, the rock being composed of actinolite with Si apfu ca. 8.0, diopside (also megacrysts), and silver-coloured löllingite with metallic lustre, although carbonates and quartz were also detected (Gil, 2013). Our latest investigations also revealed a tremolite nephrite variety and detected other accessory phases – apatite, scheelite, unspecified serpentine and traces of arsenopyrite and gold.

In the past, nephrite varieties removed direct from mine walls were described. The light greyish-greenish nephrite forms a 7 cm-wide “bed” in the pyroxenite. In certain parts of the “bed” the nephrite has a reddish hue and has only a slight slaty fabric. The nephrite is – mostly – of massive fabric and is only in some places fibrous, namely at the edges of the “bed” where nephrite and pyroxenite contact. The rock contains a little löllingite in places (Traube, 1887).

The nephrite is extremely finely fibrous, the fibres being so thin and tightly packed that they can hardly be distinguished even at large magnification. The arrangement of fibres is in part irregular. The fabric is not everywhere homogeneous, with occasional moderately large “reed-like” amphibole clusters and knots. Sporadically, fine, tabular pyroxenes are present. Along the cleavage of the sparsely-occurring coarse-grained augites, there is finely fibrous amphibole. Löllingite usually forms idiomorphic crystals. Magnetite, formed from altered pyroxene, is rare (Traube, 1887).

Microscopical examination makes it unambiguous that nephrite forms by the alteration of compact diopside. The compact diopside aggregates are extremely fine-grained. The alteration into finely fibrous amphibole can be recognized even under plane-polarized light. The amphibole-clusters forming the fine-fibrous, felted fabric often enclose pyroxene, but alteration is so advanced that in some places pyroxene is no longer recognizable. This type of facies is very similar to the Jordanów “pyroxene-amphibole rock” (i.e., formation by way of uralitization of a compact pyroxene lithology; Traube, 1887).

[Light greyish-greenish nephrite (“pyroxene-amphibole rock”: I.); (diopside coated with tremolite-asbestos: II.); (fresh diopside-pyroxenite: III.) (Traube, 1887); green nephrite with löllingite (see Fig. 7B: PGAA 1); pale green nephrite (see Fig. 7C: PGAA 2)]