



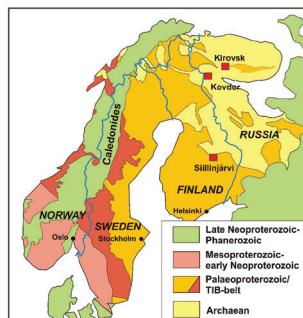
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## POTENTIAL PHOSPHATE ROCK RESOURCES IN NORWAY

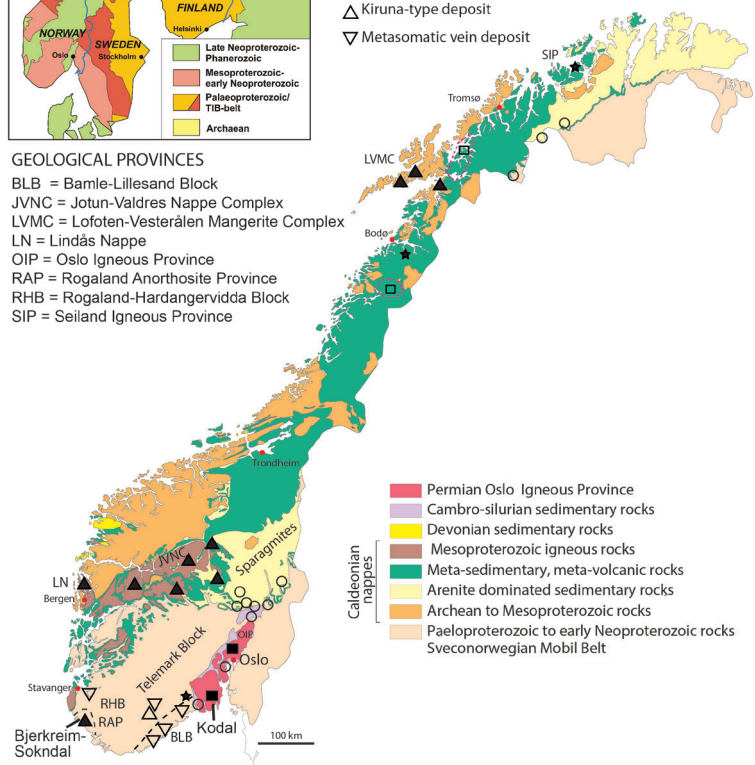
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A large variety of phosphate-rock deposits and occurrences are found in Norway (<http://dx.doi.org/10.1016/j.oregeorev.2013.11.003>, and references therein). They include sedimentary, igneous and hydrothermal deposits. The former comprises low-grade phosphorite accumulations in Late Neoproterozoic to Early Paleozoic shale-siltstone sequences along the eastern margin of the Caledonides. The other types of phosphate rocks are composed of crystalline apatite, i.e. mainly fluor-apatite in igneous deposits, and chlorine-rich apatite in hydrothermal veins.

The igneous deposits which appear to have the greatest potential for exploitation in the future, occur in association with anorthosite-mangerite-charnockite-granite (AMCG) complexes and carbonatite-bearing alkaline complexes. The AMCG complexes carry apatite (ap)-rich intrusions of nelsonites and pyroxenites to leuconorites of Paleo- (LVMC, JVNC), Meso- (JVNC) and Neoproterozoic age (RAP, LN, JVNC). These intrusions are also characterized by high concentrations of Fe-Ti oxides, in contrast with the general low content of oxides in the phosphorite-rich intrusions of the alkaline complexes.



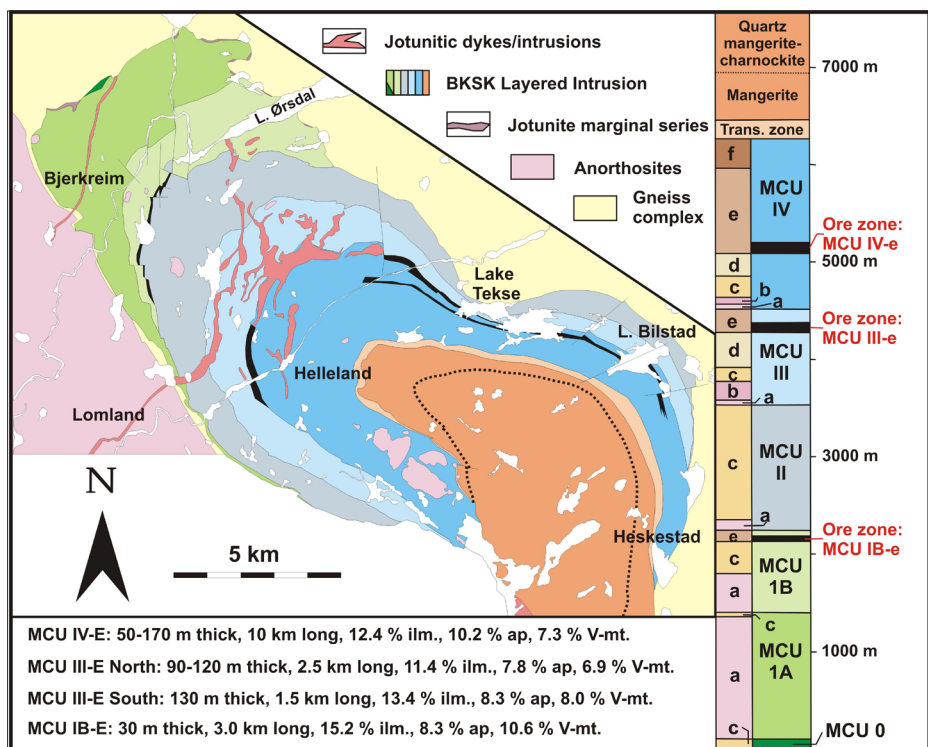
**GEOLOGICAL PROVINCES**  
 BLB = Bamle-Lillesand Block  
 JVNC = Jotun-Valdres Nappe Complex  
 LVMC = Lofoten-Vesterålen Mangerite Complex  
 LN = Lindås Nappe  
 OIP = Oslo Igneous Province  
 RAP = Rogaland Anorthosite Province  
 RHB = Rogaland-Hardangervidda Block  
 SIP = Seiland Igneous Province



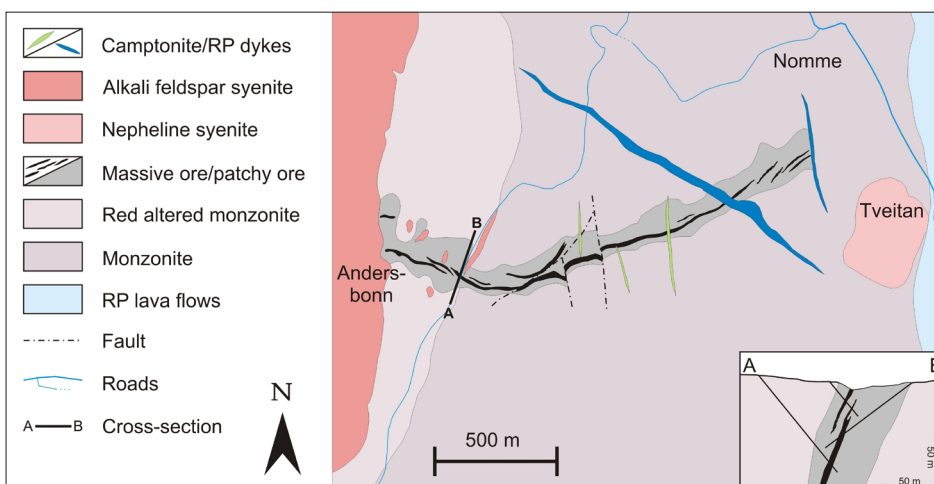
**DEPOSIT TYPES**

- Phosphorite occurrence
- Stratiform Fe-P deposit
- ★ Deposit in alkaline complex
- ▲ Deposit in AMCG complex
- Deposit in monzonite complex
- △ Kiruna-type deposit
- ▽ Metasomatic vein deposit

Presently, the most promising phosphate rock resource in Norway is found in the leuco-noritic Bjerkreim-Sokndal Layered Intrusion (BKSJ) in the AMCG complex of Rogaland (RAP). It is composed of six megacyclic cumulate units (MCU) situated in an open synformal structure. Each unit comprises one or more members with bulk compositions ranging from anorthosite (A) via troctolite (B) and norite (C) to gabbronorite (E, F) in the upper part, where high-grade Fe-Ti-P ore zones are developed. These include the ore zones in the MCU IB-E, III-E and IV-E (see photo). As shown in the figure the ore zones contain a total of 26-34 % value minerals, i.e. apatite (ap), ilmenite (ilm) and vanadium-rich magnetite (V-mt).



The sub-alkaline and alkaline igneous rocks of the Permian OIP include clino- and orthopyroxene-bearing monzonitic intrusions which host dyke-like bodies of ore-bearing olivine clinopyroxenites. These are surrounded by monzonites infiltrated by cm- to dm-sized veinlets and patches of ore. The Kodal deposit is the largest of this type. It comprises massive ores with modes in the range 10-24 % apatite, 5-15 % ilmenite, 25-60 % titaniferous magnetite and 25-50 % mafic silicates. Kodal Minerals Ltd has calculated indicated+inferred ore reserves to 49 Mt with about 12 wt.% apatite (<http://www.kodalminerals.com>) which contains ca. 1 wt. % REO. The deposit is comparable to many P-Fe-Ti-rich ores found widespread in mangerites of the Paleoproterozoic AMCG-province in Lofoten-Vesterålen in northern Norway (LVMC).



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