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# Old Ultramafic Soils with Ferruginous Black Nodules along the Western Margin of the Klamath Mountains, California and Oregon

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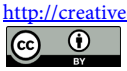




## Abstract

The Klamath Mountains of the Mesozoic and early Cenozoic were reduced to a peneplain in the Miocene. Subsequently, the mountains have risen thousands of meters and been dissected by erosion. Along the western margin of the Klamath Mountains, in areas where the peneplain has not risen more than a few hundred meters, there are remnants of the peneplain with some very old ultramafic soils that have black, magnetic nodules in the surface horizons. Maghemite is the magnetic mineral in the nodules, although the soils have much more iron (Fe) in goethite. There is no more than a possible trace of any manganese oxide mineral in the nodules. The ferruginous nodules are in soils that are well drained and have reddish hues. There are nearly 50 thousand hectares of soils with black nodules in Klamath Mountains. They are in ferruginous Kanhapludalfs and Kandihumults, and a few hundred hectares of ferritic Kandihumults. Soils with ferruginous and ferritic black noddles are sparse in California, but common in ultramafic soils on islands in the Caribbean sea.

## Keywords

Ultramafic Strata, Very Old Soils, Iron, Magnetic Nodules

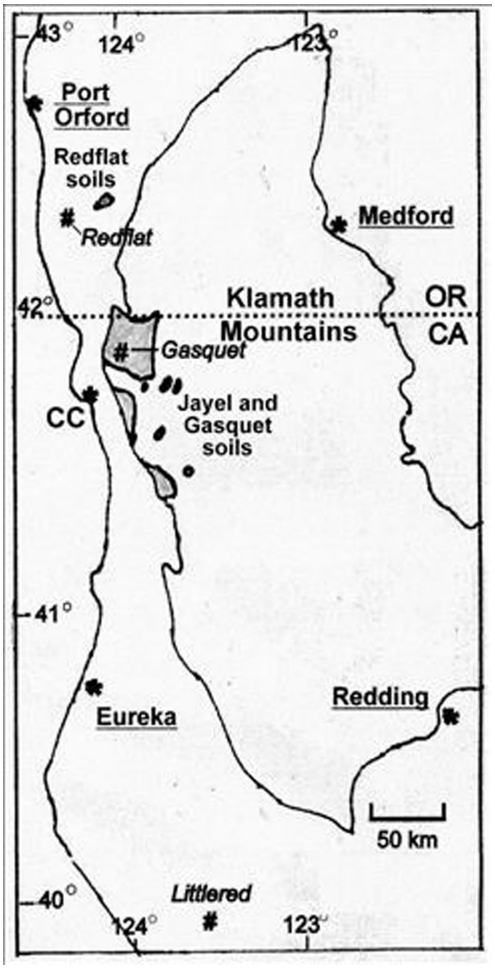
## 1. Introduction

Black, nodular fine pebbles and coarse sand grains are common in the surface horizons of very old soils, millions of years old, in Miocene ultramafic materials along the western margin of the Klamath Mountains (Figure 1). The nodules are attracted to a small magnet. The magnetic black nodules are in the Gasquet, Jayel, Redflat, and Littlered soils. They were called *shot-sized nodules* in the official se-

ries description (OSD) of the Jayel Series, not mentioned in the Gasquet Series description, and *manganese concretions* in the OSD of the Redflat Series.

Placer miners have recognized the nodules as *iron-shot* for decades. And geologists have identified the chemical and mineralogical composition of the black nodules in laboratory investigations [1] [2]. But soil surveyors do not appear to have been aware of the geological investigations.

The current objective is to characterize the black nodules and review their occurrences along the western margin of the Klamath Mountains.




#Locations where soils were described by Alexander, Gasquet and Littlered [5] and Redflat [6]. CC. Crescent City.

**Figure 1.** Locations of soils with black nodules. The areas of soils with black nodules contain some soils lacking black nodules, also. The Jayel and Gasquet soils are in the Klamath Mountains, the Redflat soils are in strata over-thrust onto Coast Ranges strata, and the Littlered soils are on a peneplain southwest of the Klamath Mountains. Data sources: [3] [4].

## 2. Geological Setting

The Klamath Mountains of the Mesozoic and early Cenozoic were reduced to a peneplain in the Miocene [7]. A peneplain was confirmed by the presence of

stream sediments containing minerals found in the Idaho Batholith, but not in the Klamath Mountains, that were carried across the peneplain and deposited in Miocene sediments along the western margin of the Klamath Mountains [8]. Since the Miocene, the Mountains have been uplifted thousands of meters. They have been dissected and severely eroded, limiting soil development. However, there have been only a few hundred meters of uplift along much of the western margin of the peneplain and erosion there has been less extensive than in the higher mountains. Even though the larger western rivers are in deep canyons, there are remnants of the peneplain that have very old soils on them.

The very old soils (Table 1) are generally well drained and there is much iron in those with ultramafic parent materials. Black nodules are common in the surface soil horizons of the very old soils and occur in some subsoils. The soils have mesic soil temperature regimes and the annual precipitation is about 200 to 300 cm, mostly in winter.

Table 1. Soils with ferruginous black nodules.

| Soil | Area (ha) | Soil sample sites | | Soil Class | Depth |
|---|---|---|---|---|---|
| | | Location | Altitude | | |
| Gasquet | 12,874 | 41.885˚ Lat<br>−123.994o Long. | 705 m<br>171 m | ferruginous Kandihumults | v. deep |
| Jayel | 32,426 | no sample | ——<br>267 m | ferruginous Kanhapludalfs | mod. deep to deep |
| Redflat | 3,913 | 42.3725˚ Lat.<br>−124.298o Long. | 540 m<br>610 m | ferruginous Kanhapludalfs | v. deep |
| Littlered | 870 | 39.910˚ Lat.<br>−123.665˚ Long. | 1195 m<br>830 m | ferritic Kandihumults | v. deep |

Altitude: meters above sea level (asl) at soil sample sites and at OSD (official soil series) locations; for example, Gasquet soil sample site at 705 m and official series site at 171 m. Areas are from the OSD descriptions of the NRCS. Soil classification is based on data from [5] [6].

## 3. Methods

Characterization of very old Klamath Mountain soils with black nodules in California [5] is supplemented by data from the Redflat soil in Oregon [6]. The A and B horizons of the Redflat soil were sampled at 0 - 12 and 30 - 48 cm depths in a transect across the Klamath Mountains [6]. Data from those samples at 42.375˚ latitude an d −124.30˚ longitude, about 100 meter north of the official soil series site location of the NRCS (Natural Resources Conservation Service) at 42.3725˚ lat. and −124.298˚ long. is a main source of information for the current characterization of the Redflat soil and its black nodules. Sand grains from the 0 - 12 and 30 - 48 cm soil depths were identified with a petrographic microscope, and a soil sample of fine earth (soil passed through a 2 mm sieve) from the 0 - 12 cm depth was sent to a commercial laboratory for aqua regia digestion and chemical element

analysis [6]. Black nodules from the Jayel soil were dissolved in concentrated hydrochloric acid to observe the color of the solution.

## 4. Results

The Gasquet and Jayel soils are in the Klamath Mountains and the Redflat soils are in deposits of serpentinized peridotite along the western margin of the Klamath Mountains. The Redflat soils are on a mountain bench in a sheet, or slabs, of rock thrust over Coast Ranges strata [2] [8]. A photograph of the soil where it was sampled on a transect across Klamath Mountains and adjacent terrane [6] is shown in **Figure 2**. The thick cover of pine trees and shrubs at that site is shown on the cover of a book [9]. The Redflat soil (**Figure 2**) is deep, with a thin A-horizon containing black modules, and an argillic B-horizon, although its argillic B-horizon is not recognized in the OSD of the NRCS. The black nodules are attracted to a hand-held magnet, which implies that magnetite and/or maghemite are major components of the black nodules. Dissolution of black nodules from the surface of the Jayel soil (**Figure 3**), sampled about 70 km south of Redflat by Ryan O'Dell, yielded a yellow liquid (10YR hue), which is indicative of ferric iron, $Fe^{3+}$ [10]. This and the magnetism implicate maghemite, but do not exclude the presence of goethite in the nodules. Colors with red hues in the B-horizon of a soil with ferruginous noddles, as shown in a thin-section (Fig.3-4D in [9]) indicate the presence of hematite [11], and there is some hematite in A-horizons, as confirmed by X-ray diffraction (**Figure 4**).

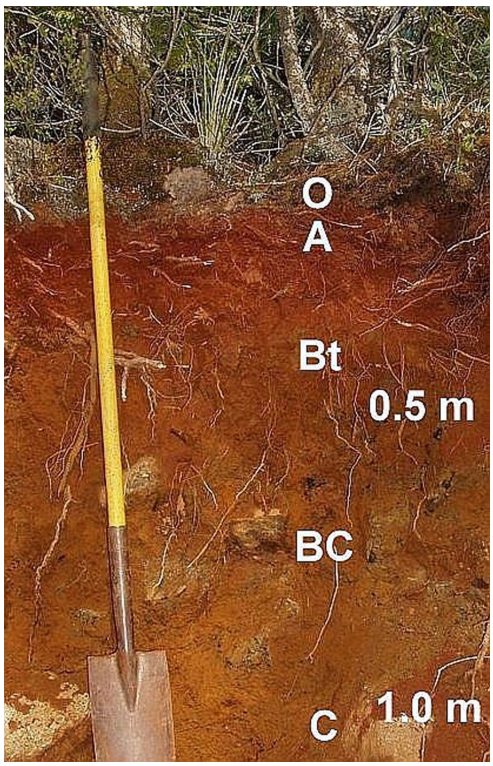



**Figure 2.** Redflat soil sampled on a Klamath Mountain transect [6].


Figure 3. Black nodules on the surface of the Jayel soil. Photograph by Ryan O'Dell. Erosion has concentrated nodules on the surface of the soil. There is enough soil on the nodules to make them look more brown than black.

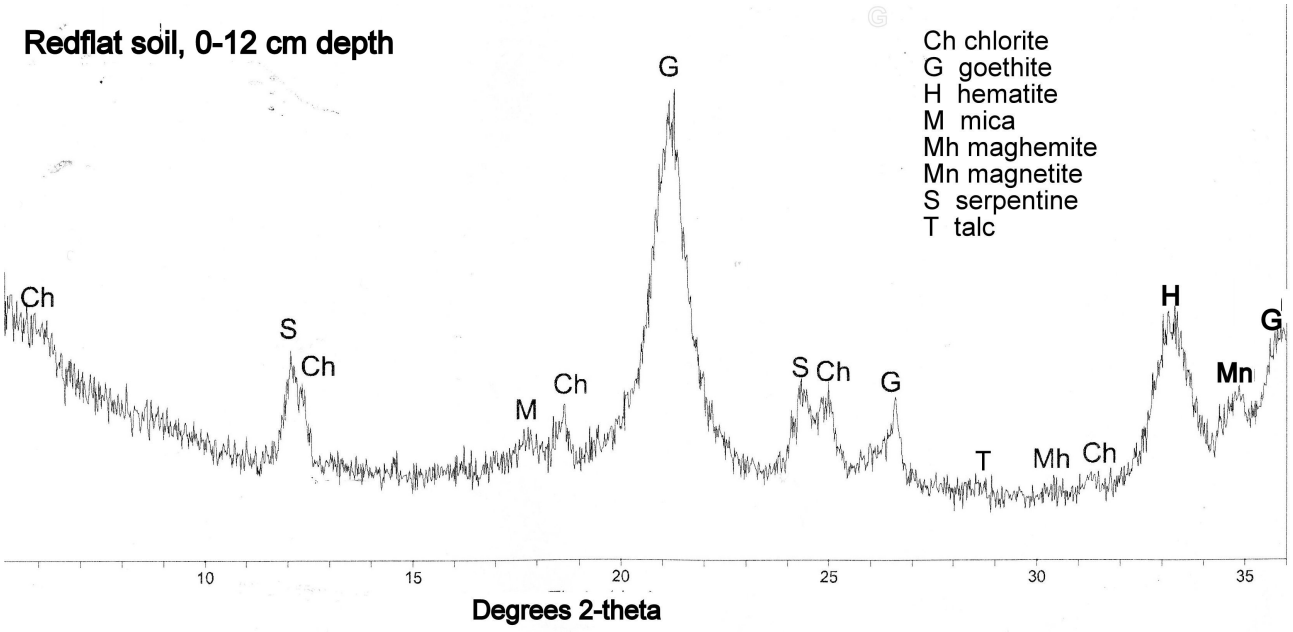



Figure 4. An X-ray diffractogram of fine earth (0 - 2 mm) from 0 - 12 cm depth in the A-horizon of the Redflat soil.

Although black nodules in the Redflat soil were referred to as manganese concretions in the OSD, Hotz [1] found no Mn minerals in the gravel or sand, although he did identify specs and thin, discontinuous coatings of MnO on some

grains. "The shot-like granules, which are commonly found in the surface of the Redflat soil and are moderately to strongly magnetic appear optically to be composed mostly of maghemite and lesser amounts of goethite [1]." Similar black sand grains in coarse sand of the Gasquet soil, about 80 km south of the Redflat OSD site were practically all magnetic, as observed with a hand-held magnet [5]. Hematite is responsible for the reddish hues of B-horizons.

Redflat soil was sampled at 0 - 12 and 30 - 48 cm depths [6]. Aqua regia digestion of soil < 2 mm indicated that there is no more than 5 g/kg of Mn and more than 50 g/kg of iron in the upper 12 cm of the soil (**Table 2**). Coarse sand grains observed with a petrographic microscope were, other than weathered unidentifiable grains, orthopyroxene >> serpentine, & chlorite > olivine, black nodules, clinopyroxene, & talc. The same minerals are present in the subsoil, but no black nodules. Goethite is the main clay mineral in the subsoil, and serpentine, chlorite, and maghemite are definitely present, and possibly magnetite. Magnetism of the black nodules confirms that maghemite is a major mineral in them, but it does not exclude goethite in the nodules.

**Table 2.** Contents of some chemical elements in the Redflat, Gasquet, and Littlered soils.

| | Hor. | Mg | Al | Si | Cr | Mn | Fe | Co | Ni |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | g/kg | | | | |
| Redflat | A1 | --- | 32.5 | --- | 2.3 | 4.9 | >50 | 0.4 | 4.1 |
| Gasquet | Bt | 22.8 | 25.3 | 8.9 | 19.9 | 2.4 | 38.0 | 1.1 | 7.5 |
| Littlered | Bt | 37.6 | 32.3 | 15.6 | 31.6 | 3.9 | 31.8 | 0.6 | 10.1 |
| USA, 20 cm depth | | 0.9 | 7.2 | 31 | <0.1 | 0.1 | 2.6 | <0.1 | <0.1 |

Analytical methods; Redflat soil, aqua regia digestion [6], Gasquet and Littlered soils. X-ray fluorescence [5]. Sample depths: A1 (0 - 12 cm), Bt1 (30 - 48 cm). USA, means of 1318 soil samples from the 48 contiguous states [12].

Clay films or coating are commonly faint or obscure in ultramafic soils, but were observed in the Redflat soil. Therefore, the Redflat soil is referred to as a Kanhapludalf. The older Gasquet soil in the Klamath Mountains, and the Littlered soils on the sparse ultramafic rocks of the Bellsprings peneplain southwest of the Klamath Mountains, in California, also have magnetic black nodules in them. The Gasquet and Littlered soils were referred to as ferruginous and ferritic Kandihumults [5].

Plant cover on the soils with ferruginous nodules is mostly pine trees and a variety of shrubs (**Table 3**). The pine trees are mostly lodgepole (*P. contorta*), and white pine (*P. monticola*) on the Gasquet and Redflat soils. And Jeffrey (*P. jeffreyi*) and sugar pine (*P. lambertiana*) on the Littlered soils. Knobcone pine (*P. attenuata*) is present on all of the soils, including the Jayel soil. Potential timber productivity is low on the very deep soils and very low on the moderately deep soils [4], it might be slightly higher on more completely weathered Littlered soil.

**Table 3.** Plants at soil sample sites [5] [6] and at the NRCS type location of the Jayel soil.

| Plant species | | Jayel | Gasquet | Redflat | Littlered |
|---|---|---|---|---|---|
| *Pinus attenuata*, knobcone pine | tree | x | t | x | x |
| *Pinus contorta*, lodgepole pine | tree | | xx | xx | |
| *Pinus jeffreyi*, Jeffrey pine | tree | | | | xx |
| Pinus *lambertiana*, sugar pine | tree | xx | | | xx |
| *Pinus monticola*, white pine | tree | | xx | xx | |
| *Calocedrus decurrens*, incense-cedar | tree | | | | x |
| *Chamaecyparis lawsoniana*, Port Orford-cedar | tree | | | t | |
| *Pseudotsuga menziesii*, Douglas fir | tree | t | t | | |
| *Notholithocarpus densiflorus*, tanoak | tree | | | | |
| *N. densiflorus* var. *echinoides* | shrub | x | xx | xx | t |
| *Arctostaphylos canescens*, hoary manzanita | shrub | | | x | xxx |
| *Frangula californica*, California coffeeberry | shrub | x | x | | |
| *Garrya buxifolia*, California silktassel | shrub | | t | | |
| *Quercus vaccinifolius*, huckleberry oak | shrub | x | t | | x |
| *Rhododendron macrophyllum,* rhododendron | shrub | | t | x | |
| *Rhododendron occidentale,* azalea | shrub | x | t | t | |
| *Umbellularia californica*, California bay | shrub | x | t | t | |
| *Vaccinium ovatum*, California huckleberry | shrub | x | | x | |
| *Vaccinium parvifolium*, red huckleberry | shrub | x | x | x | |
| *Xerophyllum tenax*, bear-grass | forb | | x | x | |

Low or prostrate shrubs, not extensive: *Arctostaphylos nevadensis*, *Ceanothus pumilus, Juniperus communus*. Forbs, sparse or traces*: Anemone oregona, Erithronium citrinum, Iris* sp., *Lupinus sp.*, *Pedicularia* sp., *Phlox diffusa, Viola lobata*. Grasses, sparse: *Festuca idahoensis* and *F. californica.* Ferns are sparse.

## 5. Other North American Soils with Ferruginous Black Nodules

Soils with ferruginous black nodules or concretions are scarce on the North American Craton, an area which is shown an the back cover of a book [9]. There is a unique occurrence of soils with black nodules in the Appalachian Blue Ridge Mountains, where they are in the Ellijay soils, ferruginous Kanhapudalfs. The Ellijay soils are on an ultramaic ring dike around Webster, North Carolina. They have black "concretions" in the subsoil, or saprolite. The area of Ellijay soils is about 110 ha.

Soils with ferruginous black nodules are common on many islands in the Caribbean Sea. The Nipe and some associated soils are representative of the ultramafic soils with black nodules. The Nipe are ferruginous Acrudox soils that generally have black "concretions" in the surface (A) horizons, and commonly in subsoils,

also. There are thousands of hectares of Nipe and similar soils in Cuba and Puerto Rico, and on many other islands in the Caribbean Sea.

## 6. Conclusions

Ferruginous nodules are in soils with much iron. They are much less common than manganese nodules. Ferruginous nodules are readily distinguished by being magnetic; they are attracted to a small magnet. Ferruginous nodules are concentrated in the upper horizons of well drained soils and manganese nodules are generally in subsoils of poorly or somewhat poorly drained soils.

Maghemite is the magnetic mineral in ferruginous nodules, although. There is more goethite. Goethite is the main iron bearing mineral in the A-horizons and hematite is a dominant mineral in the red B-horizons of the very old ferruginous soils.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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