the presented directory of Phanerozoic ooidal ironstones could become a helpful tool in this respect.

Directory of world-wide Phanerozoic ooidal ironstones

In each deposit the local name of the ooidal ironstone, or less commonly just "ooidal ironstone", is given. Full names of contributors (authors) responsible for data on particular ironstone deposits are usually given in the reference at the end of the description of particular deposits. On the other hand, the following names with years indicate the essential sources of information as submitted by individual contributors (for full names and detailed quotation see the References at the end of the directory).

The descriptions of ironstone deposits were assembled from all over the world in the course of several years. Not only contain these descriptions the objective facts but also some arbitrary views and interpretations of the contributors (concerning classification of the facies, the tectonic setting, the relation to sea-level changes, diagenetic transformation, etc.). Unless stated otherwise the ooidal ironstones are of marine origin.The diversity of views is also reflected in the nomenclature of iron-bearing minerals (chlorites, limonite, goethite, hydrogoethite, hematite, hydrohematite, etc.).

Different degree of recognition has depended on methods used by researchers – this concerns especially the clay minerals (frequently chamosite of earlier authors is berthierine in reality). However, the data as existing in the literature and as submitted by contributors had to be accepted.

This also applies to some extent to the geographical nomenclature (e.g. Jebel, Djebel, Jbel of Arabic countries) and transcription of geographic names. In many cases the up to date information on the recent status of mining activities or dating of their ending has not been readily available.

References following the directory contain over 300 quotations mostly related to the described ironstone deposits. Therefore, the References cannot be considered as a representative and exhausting list covering all aspects of mineralogy, geochemistry, petrology, origin, etc. of Phanerozoic ooidal ironstones.

Algeria

Early Ordovician

1 – Dra El Kelba ooidal ironstone

In Saoura Branch, eastern Ougarta, in northwestern Algeria. In folded strata. An uneconomic deposit.

Age: Early Ordovician (Early Tremadocian). In Foum Tineslem Formation.

Major facies: A shallow shelf.

The ironstone 1 m thick is associated with fine-grained sandstone and glauconite.

The ooids are chamosite, goethite and siderite.

Main chemical composition (%): Fe 16.3, SiO_2 59.61, Al_2O_3 10.89, P_2O_5 0.41.

Ref.: Guerrak, 1991.

2 – Djebel Merenda and Djebel Naitjat ooidal ironstones

In Daoura Branch, western Ougarta, in northwestern Algeria. In folded strata. Uneconomic deposits.

Age: Early Ordovician (late Arenigian). Top of Kheneg El Aatene Formation.

Major facies: A shallow shelf.

The ironstones 2–3 m thick are enclosed by mudstone and fine-grained sandstone.

The ooids are chamosite, goethite, and hematite.

Main chemical composition (%): Merenda Fe 25.17, SiO_2 6.58, Al_2O_3 6.67, P_2O_5 1.63; Naitjat Fe 41.92, SiO_2 16.58, Al_2O_3 3.96, P_2O_5 4.07.

Ref.: Guerrak, 1991.

Middle Ordovician

3 – Djebel Reboub and Gara Haouia East ooidal ironstones

In Saoura Branch in eastern Ougarta (Reboub) and in Daoura Branch in western Ougarta (Haouia), northwestern Algeria. In folded strata. Uneconomic deposits.

Age: Early Ordovician (late Llanvirnian). In Foum el Zeidiya Formation.

Major facies: A shallow shelf.

The ironstones 0.5 to 1.3 m thick are enclosed in siltstone and sandstone.

The ooids are chamosite and goethite.

Main chemical composition (%): Reboub Fe 43.65, SiO_2 13.47, Al_2O_3 3.08, P_2O_5 3.56; Haouia Fe 41.74, SiO_2 19.54, Al_2O_3 5.37, P_2O_5 2.36.

Ref.: Guerrak, 1991.

Late Ordovician

4 – Guelb Berrezouk South, Djebel Atinim, Gara Haouia South East, and Djebel Zerhamra ooidal ironstones

In Daoura Branch in western Ougarta, and in Saoura Branch in eastern Ougarta (Zerhamra), northwestern Algeria. In folded strata. Uneconomic deposits.

Age: Late Ordovician (Caradocian).

Major facies: A shallow shelf.

The ironstones 0.20 to 2.8 m thick are enclosed in mudstone and sandstone.

The ooids consist of chamosite, goethite, hematite, and quartz (Berrezouk and Atinim), or goethite, hematite, and quartz (Haouia and Zerhamra).

Main chemical composition (%): Fe 16.22–40.16, SiO_2 17.7–69.78, Al_2O_3 0.95–5.3, P_2O_5 0.78–2.92.

Ref.: Guerrak, 1991.

5 – Djebel Atinim East ooidal ironstone

In Daoura Branch in western Ougarta, northwestern Algeria. In folded strata. An uneconomic deposit.

Age: Late Ordovician (Ashgillian).

Major facies: A shallow marine shelf.

The ironstone 2 m thick is enclosed in mudstone, siltstone, and sandstone.

The ooids are chamosite, goethite, quartz, and siderite.

Main chemical composition (%): Fe 37.08, SiO_2 26.02, Al_2O_3 6.10, P_2O_5 2.35.

Ref.: Guerrak, 1991.

6 – Ooidal? ironstone

In the north margin of Tenere du Tamesna Basin, southernmost Algeria.

Age: Earliest Late Ordovician. At top of Azaoua sandstone.

Major facies: A shallow sea.

The Azaoua sandstone, 20–30 m thick, is cross-bedded. It is overlain by Late Ordovician shale. The ironstone is very thin-bedded.

Ref.: Deynoux et al., 1985.

Silurian

7 – Zemila ooidal ironstone

In eastern southern Tindouf Basin, west-central Algeria. In folded strata. An uneconomic deposit.

Age: Early Silurian (Llandoverian).

Major facies: A shallow shelf.

The lens of ironstone is up to 9 m thick.

The ooids are goethite, hematite, chamosite, and calcite.

Main chemical composition (%): Fe 14.12, SiO_2 67.47, Al_2O_3 2.35, P_2O_5 0.73.

Ref.: Guerrak, 1991.

8 – Fedj Mlehas ooidal ironstones

In easternmost southern Tindouf Basin, west-central Algeria. In folded strata. Uneconomic deposits.

Age: Early-Late Silurian (Wenlockian-Ludlowian).

Major facies: A barrier bar with deltaic influence.

The two lenses of ironstones 1 to 6.8 m thick are enclosed in mudstone.

The ooids consist of hematite, chamosite, goethite, quartz, and calcite.

Main chemical composition (%): Fe 32.2, SiO_2 37.29, Al_2O_3 2.33, P_2O_5 2.15.

Ref.: Guerrak, 1991.

Early Devonian

9 – Atafaitafa ooidal ironstones

In Tassilis N'Ajjer, east-central Algeria. In folded strata. Possibly future potential.

Age: Early Devonian (Lochkovian).

Major facies: A marine barrier bar.

Two ironstones 1 to 10 m thick are enclosed in siltstone, sandstone, and conglomerate.

The ooids are goethite, hematite, chamosite, and quartz.

Main chemical composition (%): Fe 30.68, SiO_2 55.34, Al_2O_3 5.5, P_2O_5 0.94.

Ref.: Guerrak, 1991.

10 – Talus a Tigillites ooidal ironstones

In Tassilis N'Ajjer, east-central Algeria. In folded strata. Possibly future potential.

Age: Early Devonian (Lochkovian to Pragian).

Major facies: A shallow sea.

The ironstone 5 m thick is enclosed in sandstone and siltstone.

The ooids are goethite, hematite, chamosite, and quartz.

Main chemical composition (%): Fe 34.68, SiO_2 34.29, Al_2O_3 1.79, P_2O_5 1.79.

Ref.: Guerrak, 1991.

11 – Trottoirs ooidal ironstone

In Tassilis N'Ajjer, east-central Algeria. In folded strata. Possibly future potential.

Age: Early Devonian (Pragian).

Major facies: A shallow marine shelf.

The ironstone 4 m thick is enclosed in siltstone and sandstone.

The ooids consist of hematite, goethite, chamosite, and quartz.

Main chemical composition (%): Fe 23.66, SiO_2 46.85, Al_2O_3 3.3, P_2O_5 0.89.

Ref.: Guerrak, 1991.

12 – Orsine ooidal ironstone

In Tassilis N'Ajjer, east-central Algeria. In folded strata. Possibly future potential.

Age: Late Early Devonian (Emsian).

Major facies: A shallow marine shelf.

The ironstone 2 m thick is enclosed in mudstone and sandstone.

The ooids are chamosite and goethite.

Main chemical composition (%): Fe 34.41, SiO_2 15.74, Al_2O_3 3.33, P_2O_5 2.26.

Ref.: Guerrak, 1991.

13 – Ain Ech Chebbi ooidal ironstone

In Bled El Mass (Ahnet Basin) in central Algeria. In folded strata. An uneconomic deposit.

Age: Early Devonian (Pragian).

Major facies: A shallow marine shelf.

The ironstone 80 cm thick is enclosed in mudstone.

The ooids are goethite and chamosite.

Main chemical composition (%): Fe 44.7, SiO_2 11.5, Al_2O_3 8.12, P_2O_5 1.85.

Ref.: Guerrak, 1991.

14 – Aouinet Gara Sefra, Tguililet El Hamra, Nba, Fedj Mtaigat, Fedj Mlehas, and Gour Jiffa ooidal ironstones

In central southern Tindouf Basin (Aouinet) and easternmost southern Tindouf Basin (the rest), west-central Algeria. In folded strata. Uneconomic deposits.

Age: Early Devonian (Lochkovian).

Major facies: A shallow marine shelf, or a barrier bar with deltaic influence (Mtaigat, Mlehas, and Jiffa).
As many as 8 lenses of ironstone 0.2 to 7 m thick are enclosed in mudstone and fine-grained sandstone.
The ooids are goethite, hematite, chamosite, calcite, and quartz.
Main chemical composition (%):

	Fe	SiO_2	Al_2O_3	P_2O_5
Aouinet	25.64	19.54	2.78	1.58
Tguililet	43.98	20.28	3.36	2.74
Nba	33.84	34.09	2.86	1.91
Mtaigat	36.02	27.10	3.46	3.24
Mlehas	36.94	25.36	3.24	2.00
Jiffa	30.31	33.44	3.70	1.93

Ref.: Guerrak, 1991.

15 – Gara Djebilet and Zemila ooidal ironstones

In the central (Djebilet) and eastern (Zemila) southern Tindouf Basin, west-central Algeria. In folded strata. Possibly future potential.
Age: Early Devonian (Pragian).
Major facies: A marine barrier bar (Djebilet) and a shallow shelf (Zemila).
Several lenses of ironstones 4.5 to 15 m thick are enclosed in mudstone and muddy sandstone.
The Djebilet ooids are chamosite, goethite, hematite, magnetite, maghemite, and apatite.
Main chemical composition of the Djebilet samples (%): Fe 51–59, SiO_2 4.8–5.1, Al_2O_3 3.8–4.4, P_2O_5 1.8–1.9.
Ref.: Guerrak, 1991.

Middle Devonian

16 – Meredoua ooidal ironstone

In Ahnet in central Algeria. In folded strata. An uneconomic deposit.
Age: Middle Devonian (early Eifelian).
Major facies: A shallow marine shelf.
The ironstone 4 m thick is enclosed in mudstone and limestone.
The ooids are goethite, hematite, chamosite, and calcite.
Main chemical composition (%): Fe 18.8, SiO_2 41.5, Al_2O_3 5.72, P_2O_5 0.98.
Ref.: Guerrak, 1991.

Late Devonian

17 – Foum Belrem ooidal ironstone

12
In Ahnet in central Algeria. In folded strata. An uneconomic deposit.
Age: Late Devonian (early Frasnian).
Major facies: A shallow marine shelf.
The ironstone 4 m thick is enclosed in mudstone.
The ooids are chamosite, hematite, goethite, and calcite.
Main chemical composition (%): Fe 39.5, SiO_2 4.1, Al_2O_3 2.43, P_2O_5 1.94.
Ref.: Guerrak, 1991.

18 – In Heguis ooidal ironstones

In Ahnet in central Algeria. In folded strata. Uneconomic deposits.
Age: Late Devonian (early Famennian).
Major facies: A shallow marine shelf.
The three ironstones 1 to 4 m thick are enclosed in mudstone.
The ooids are chamosite, hematite, and goethite.
Main chemical composition (%): Fe 39.34–52.67, SiO_2 7.3–18.5, Al_2O_3 4.5–7.93, P_2O_5 2.32–3.58.
Ref.: Guerrak, 1991.

19 – Oguilet Laroussi and Mecheri Abdelaziz ooidal ironstones

In eastern southern Tindouf Basin, west-central Algeria. In folded strata. Possibly future potential.
Age: Late Devonian (Famennian).
Major facies: A prograding delta to barrier bar.
The many lenses of ironstones 0.5 to 10 m thick are enclosed in mudstone and sandstone.
The Mecheri Abdelaziz ooids consist of magnetite, hematite, maghemite, chamosite, goethite, apatite, quartz, and calcite.
Main chemical composition of the Mecheri Abdelaziz samples (%): Fe 40.57–54.83, SiO_2 8.16–15.65, Al_2O_3 3.4–5.65, P_2O_5 1.8–3.02.
Ref.: Guerrak, 1991.

20 – Djebel Illerene ooidal ironstones

In Tassilis N'Ajjer, east-central Algeria. In folded strata. An uneconomic deposit.
Age: Late Devonian (late Famennian).
Major facies: A shallow marine shelf.
Two ironstones 0.5 to 2 m thick are enclosed in mudstone and sandstone.
The ooids are composed of goethite or chamosite and goethite.
Main chemical composition (%): Fe 18, SiO_2 61.23, Al_2O_3 1.57, P_2O_5 1.43, or Fe 33.72, SiO_2 15.65, Al_2O_3 5.8, P_2O_5 9.6.
Ref.: Guerrak, 1991.

21 – Djebel Hassi ooidal ironstone

In Mouima Ahnet (Ahnet Basin), central Algeria. In folded strata. An uneconomic deposit.
Age: Late Devonian (late Famennian).
Major facies: A shallow marine shelf.
An ironstone 2 m thick is enclosed in siltstone and mudstone.
The ooids consist of chamosite, hematite, and goethite. Main chemical composition (%): Fe 46.76, SiO_2 9.7, Al_2O_3 6.17, P_2O_5 2.73.
Ref.: Guerrak, 1991.

22 – Azzel Matti ooidal ironstone

In western Ahnet Basin, in central Algeria. In folded strata. An uneconomic deposit.

Age: Late Devonian (late Famennian).

Major facies: Shallow marine shelf.

The ironstone 3.5 m thick is enclosed in mudstone.

The ooids are hematite, chamosite, goethite, magnetite, and maghemite.

Main chemical composition (%): Fe 50.24, SiO_2 6.6, Al_2O_3 3.43, P_2O_5 6.9.

Ref.: Guerrak, 1991.

Middle Jurassic

23 – Ain Djeraoua, Lamoriciere, and Dhar Rouban ooidal ironstones

Near Tlemcen in the western Tellian Atlas, northwestern Algeria. In folded strata. Uneconomic deposits.

Age: Middle Jurassic (late Bajocian).

Ref.: Elmi, 1982; Popov, 1977.

Paleogene

24 – Ain Babouche ooidal ironstone

In the eastern Saharan Atlas Mountains, eastern Algeria. In folded and faulted strata. An uneconomic deposit.

Age: Middle Eocene.

Major facies: Shallow marine shelf.

The ironstone directly overlies limestone with phosphatic nodules.

The ooids are goethite in goethite cement.

Ref.: Popov, 1977/1978.

Argentina

Silurian

25 – Villicum, Talacasto, and Pachaco ooidal ironstones

In Villicum and Talacasto near Albardon north of San Juan, and in Pachaco near Calinpasto northwest of San Juan, southern San Juan Province, in the Precordillera Basin, west-central Argentina. In folded strata. Future potential.

Age: Early Silurian (early Llandoverian). In the upper part of the Don Braulio Formation (Villicum), in the lower part of La Chilca Formation (Talacasto), and in the Tambolar Formation (Pachaco).

Major facies: A marine offshore setting or tempestites during a local prograding in a foreland basin.

The ironstones 0.2 to 2 m thick in cross-bedded and burrowed sandstone are enclosed in mudstone.

The single and multiple ooids consist of goethite, chamosite, and hematite, with minor phosphate. The ooids are commonly ellipsoidal.

The Early Silurian ironstones came soon after the latest Ordovician glaciation.

Ref.: S. H. Peralta, I. Lanzilotta, and E. R. Uliarta. Astini, 1992.

26 – Zapla and other ooidal and peloidal ironstones

Near Palpala (Zapla) and Puesto Viejo (P. Viejo) southeast of San Salvador and in Sta. Barbara (Los Lecherongs) near San Pedro in Jujuy Province, and in Sierra del Gallo (Unchime) east of Grl. Guemes and Santa Victoria (Mecoyita) east of La Quiaca in the Salta Province, in northwest Argentina; in Sierra de la Victoria in the southernmost central Bolivia. In folded and faulted strata. Abandoned, currently exploited or have future potential.

Age: Late Silurian. In the Lipeon Formation in Argentina and Kirusillas Formation in Bolivia.

Major facies: A marine offshore shelf during regional transgression in a foreland basin.

Three beds of cross-bedded ironstones 0.9 to 12 m thick are enclosed in sandstone or mudstone, as at Los Lecherongs.

The ooids consist mainly of hematite and chamosite with minor siderite and pyrite.

Diagenetic effect: Chamosite was changed gradually to hematite.

The Zapla and Puesto Viejo average chemical composition (%): Fe_2O_3 53–65, MnO 0.03–0.09, SiO_2 indet., Al_2O_3 5.2–6.4, CaO 0.66–1.3, MgO 0.4–0.8, P_2O_5 1.17, TiO_2 0.67–0.8.

Ref.: J. C. M. Zanettini. Angelelli, 1984; Boso and Monaldi, 1990.

27 – Rosales and Alfaro ooidal ironstones

About 6 km north and south of Sierra Grande, Rio Negro Province, southeast Argentina. In folded and faulted strata. Currently exploited (Rosales) or has future potential (Alfaro).

Age: Late Silurian. In the middle of the San Carlos Member (Horizonte Rosales) and in the lower part of the Herrada Member (Horizonte Alfaro) of the Sierra Grande Formation.

Major facies: A marine offshore shelf during transgression (Rosales) or regression (Alfaro) in a foreland basin.

The lenticular ironstones 0.3 to 42 m thick (multiple) are lying above mudstone and below fine-grained sandstone.

The ooids are fresh in the mines and weathered in outcrops.

The ooids are hematite and chamosite, with minor magnetite. Phosphorite is in the matrix.

Average chemical composition (%): Fe_2O_3 69–80, MnO 0.12–0.17, SiO_2 6–18, Al_2O_3 4, CaO 1.6–3, MgO 0.43–0.46, TiO_2 0.25–0.41, P_2O_5 1.35–3.

Ref.: J. C. M. Zanettini. Zanettini, 1981.

Devonian

28 – Cerro del Rincon ooidal ironstones

Near Cerro del Rincon west of San Antonio de los Cobres in Salta Province, northwest Argentina. In folded strata. Uneconomic deposits.

Age: Early? Devonian. In the upper part of the Salar del Rincon Formation.

Major facies: A marine offshore shelf during regional transgression in a foreland basin.

The main ironstone 2–6 m thick is enclosed in fine-grained sandstone. Another ironstone 0.3 to 0.5 m thick is 35 m higher in the section.

In weathered outcrop the ooids are goethite.

The average chemical composition (%): Fe 27, MnO 0.24, SiO_2 48, TiO_2 0.22, P_2O_5 0.31.

Ref.: J. C. M. Zanettini. Lurgo, 1974.

Australia

Early Ordovician

29 – Pacoota ooidal ironstone

In Amadeus Basin in southwest Northern Territory, south and west-southwest of Alice Springs. Along about 300 km of scattered outcrops and subsurface. In dipping strata. An uneconomic deposit.

Age: Ordovician (early Arenigian). In the upper Pacoota Sandstone, about 6 m thick, in the 0.5 m uppermost part of the sandstone overlying shale.

Major facies: A reducing condition in a fairly deep sea was followed by shallower marine environment.

The ironstones are a few cm thick. Glauconite and phosphorite are also present.

Ooids in outcrops and subsurface are goethite, hematite and kaolinite, and ooids in one ironstone in subsurface is pyrite. Matrix is mainly quartz, with illite, kaolinite, and minor chlorite.

Diagenetic effect: Probably berthierine was changed to goethite, hematite, or kaolinite. The subsurface pyrite was originally siderite.

Ref.: Gorter, 1991.

Late Permian

30 – Desert Basin ooidal ironstone

In Canning Basin in northeastern Western Australia, centered on Fitzroy River and extending more than 300 km southeast of Derby. In folded sedimentary rocks. An uneconomic deposit.

Age: Late Permian; in the basal part of Liveringa Group, about 350 m thick, and consists of ferruginous and calcareous sandstone and mudstone. Fossils: casts of gastropods and pelecypods.

Major facies: Shallow sea.

The ironstone lenses lie in a ferruginous sandstone about 20 m thick at the base of the Group. Lenses are a few cm to nearly 10 m thick.

Ooids are weathered and consist of geothite, with matrix mostly of quartz and feldspar ranging from 10 to 30 per cent.

Diagenetic effect: Probably berthierine was changed to goethite.

Chemical composition of ironstone lenses (%): Fe_2O_3 38–50, MnO 0.46–0.53, SiO_2 19–34, Al_2O_3 10–12.8, P_2O_5 0.32–1.8.

Ref.: Edwards, 1958.

Jurassic

31 – Westgrove ooidal ironstone

In the Great Artesian Basin in the southeastern Queensland, about 500 km northwest of Brisbane and 80 km northeast of Charleville. In low-dipping strata. An uneconomic deposit.

Age: Early Jurassic. In Westgrove Ironstone Member, 9–24 m thick, at the top of the Evergreen Formation, 120–160 m thick, east of Mimosa Syncline. Limonitic oolite, 0–9 m thick, lies at the top of the Evergreen Formation. Hutton Sandstone conformably overlies the Evergreen Formation.

Major facies: In an anoxic shallow sea underlain by nonmarine sand, mud, and coal of the main Evergreen Formation.

In outcrop ooids are composed of goethite, hematite, or kaolinite, with "chamosite" and siderite mudstone.

Diagenetic effect: Probably the berthierine was changed to goethite, hematite, and kaolinite.

Ref. Mollan et al., 1972.

Paleogene

32 – Robe River ooidal and pisoidal ironstone

Over much of Hamersley Basin 175–220 km east-northeast of Exmouth. Also along Bungaroo Creek valley to the east. A future potential deposit.

Age: Probably Late Eocene.

Major facies: Ironstone is nonmarine deposit along ancient rivers, possibly from upland laterites in the source area.

The ironstone averages about 15 m and reaches 45 m in thickness. It contains as much as 60 percent Fe.

Ooids and pisoids are goethite and hematite with a little matrix.

Ref.: G. E. Williams. Hocking et al., 1987; Williams and Goode, 1986.

Belgium

Early Devonian

33 – Ortenville and Forge-Philippe ooidal ironstones

In the southern limb of the Dinant Syncline south of Couvin and Chimay, southwestern Belgium. In folded and faulted strata. Abandoned deposits.

Age: Early Devonian (Lochkovian). The ooids are composed of hematite.

Average chemical composition (%): Fe 43, SiO_2 17.25–21, P 1.05–1.17.

Ref.: Dejonghe, 1977/1978.

Middle Devonian

34 – Ooidal ironstone

At the southern limb of the Dinant Syncline between Wellin and Givet, southwestern Belgium. In folded and faulted strata. Abandoned mines.

Age: Middle Devonian (Eifelian).

The ironstone is limy and aluminous. The ooids are hematite. Average Fe content 35 to 42 %.

Ref.: Dejonghe, 1977/1978.

35 – Ooidal ironstone

In the southeast of Verviers on the southern side of the Vesdre Massif, southeastern Belgium. An uneconomic deposit.

Age: Late Middle Devonian (Givetian).

The ironstone is associated with shale interbedded with limestone. The ooids are hematite.

Ref.: Dejonghe, 1977/1978.

Late Devonian

36 – Ooidal ironstone

In the Meuse, Samson, and Ourthe valleys on the northern and eastern limbs of the Dinant Syncline, on the eastern part of the southern limb of the Namur Syncline, and in the Vesdre Massif. In folded and faulted strata. An uneconomic deposit.

Age: Early Late Devonian. At the base of the Frasnian between the underlying Fromelennes Limestone and the overlying black shale.

The ooids are hematite and chamosite.

Ref.: Dejonghe, 1977/1978.

37 – Oligiste oolithique and four other ooidal ironstones

In the Namur, Dinant, and Verviers synclines south of Liege in southern Belgium. In folded and faulted rocks. Uneconomic deposits.

Age: Late Devonian (early Famennian). In Lower Famennian Shale underlain by reefal limestone and overlain by the Condroz Sandstone. The ironstones are underlain by silty limestone.

Major facies: A marine setting during regional transgression in a foreland basin.

The coarsening upward ironstones are burrowed tempestites a few cm to a few tens of cm thick.

The ooids and pisoids consist of hematite and minor chamosite, sulfide, and phosphate. The matrix is quartz sand and silt and carbonate cement.

Diagenetic effect: Original ooids were changed to hematite, chamosite, and phosphate. Calcareous matrix was changed to dolomite.

Ref.: R. J. H. Dreesen. Dreesen, 1989.

38 – Couthuin ooidal ironstone

In the Marsinne area in eastern part of the north limb of the Namur syncline in southern Belgium. In folded and faulted strata. In abandoned mines.

Age: Latest Devonian (Strunian).

Major facies: A shallow sea.

The ironstone is enclosed in limestone.

The ooids are hematite, chamosite, and siderite, with various amounts of pyrite. The ironstone contains 30 to 35 % Fe.

Ref.: Dejonghe, 1977/1978.

Early Jurassic

39 – Ooidal ironstone

In Musson and Halanzy in western Belgium. In nearly horizontal strata. Abandoned mines.

Age: Late Early Jurassic (Toarcian).

Major facies: Shallow sea.

The ironstone is an extension of the ore of Lorraine, France.

The ore contains 35–39 % Fe, 0.5–0.6 % P.

Ref.: Dejonghe, 1977/1978.

Bolivia

Late Ordovician

40 – Jarcas-Negra Muerta ooidal ironstones

In the Andes in southernmost central Bolivia. In folded and faulted strata. An uneconomic deposit.

Age: Late Ordovician (Ashgillian). In the Cancaniri Formation.

Major facies: A shallow marine shelf.

The ironstones are enclosed in sandstone and mudstone.

The ooids are mostly hematite and chamosite.

Ref.: Boso and Monaldi, 1990.

Silurian

41 – Sierra de la Victoria ooidal ironstone

Southernmost central Bolivia. In folded and faulted, marine Kirusillas Formation of Late Silurian age. More extensively developed in neighbouring Argentina (see Argentina, 26 – Zapla ironstone)

Brazil

Early Silurian

42 – Trombetas ooidal ironstones

In the area of Manaus in the middle Amazon Basin, north-central Brazil. In boreholes and outcrops. Uneconomic deposits.

Age: Early Silurian (Llandoverian). In the top of Nhamunda Member and in the Manacapuru Member of the sandy and muddy Trombetas Formation.

Major facies: A marine nearshore setting, just after Early Silurian glaciation.The ooids consist of hematite and chamosite, with phosphate and siderite.

Ref.: Carozzi, 1979.

Early Devonian

43 – Urucara ooidal ironstone

In the vicinity of Manaus in the middle Amazon Basin, north-central Brazil. In a borehole. An uneconomic deposit.

Age: Early Devonian (Emsian). In the upper Maecuru Formation.

Major facies: A marine littoral zone of a distal delta.
Ref.: Carozzi, 1979.

Bulgaria

Early Jurassic

44 – Troyanska Planina ooidal ironstones

In the region south of Troyan (east) and Tetevene (west) about 100 km east of Sofia, in the central Bulgaria.

In folded and metamorphosed rocks. An uneconomic deposit.

Age: Early Jurassic (Pliensbachian and Toarcian) and Middle Jurassic (Aalenian-Bajocian-Bathonian).

Major facies: Transgression and regression in a shallow sea.

Several ooidal beds 2 to 4 m thick within shale and sandstone. Ooids consist of goethite, hematite, chamosite/berthierine, siderite, and quartz, and glauconitic peloids.

Diagenetic effect: Original berthierine ooids were changed in part to goethite and hematite.

Chemical composition (%): Fe_2O_3 18–38, MnO 0.09–0.15, SiO_2 7–32, Al_2O_3 3–18, CaO 1–21, MgO 1–3.7, P_2O_5 0.1–0.75.

Ref.: Dokov et al., 1977/1978; Nachev, 1960.

45 – Gradetz ooidal ironstones

In the vicinity of Gradetz 25 km northwest of Sofia, in western Bulgaria. In folded rocks. An uneconomic deposit.

Age: Early Jurassic (Toarcian) and Middle Jurassic (Aalenian-Bajocian).

Major facies: A shallow sea.

Ooids consist of goethite and berthierine and glauconitic peloids.

Average composition (%): Fe_2O_3 20.7, MnO 0.13, SiO_2 20.9, Al_2O_3 11.8, CaO 16.3, MgO 0.9, P_2O_5 0.94.

Ref.: Dokov et al., 1977/1978.

Middle Jurassic

46 – Dolni Lom ooidal ironstone

In the region of Dolni Lom 100 km northwest of Sofia, in northwest Bulgaria. In folded sedimentary rocks. An uneconomic deposit.

Age: Middle Jurassic (Bathonian).

Major facies: A shallow sea.

Ooids are goethite. Fe_2O_3 is 16–26 %.

Ref.: Dokov et al., 1977/1978.

Canada

Middle Cambrian

47 – Gillis Brook ooidal ironstone

At Gillis Brook near Grand Mira South in eastern Cape Breton Island, northeastern Nova Scotia. In folded metamorphic strata. An uneconomic deposit in outcrop and a few boreholes.

Age: Middle Cambrian.

In slate. The ironstone is a few cm thick. Its ooids are hematite and magnetite.

The chemical composition (%): Fe 49.36–63.76, SiO_2 4.71–13.38, P_2O_5 0.25–0.56.

Ref.: Wright, 1975.

Early Ordovician

48 – Dominion and other ooidal ironstones

In 10-km Bell Island in the south-central Conception Bay, eastern Newfoundland. Abandoned mines and outcrops. In folded strata.

Age: Early Ordovician. In the Bell Island Group (1390 m) the Beach Formation (440 m) has two ironstones 1 m thick in the early Tremadocian and early Arenigian?; the Ochre Cove Formation (65 m) has several thin ironstones of Arenigian age in the upper 20 m; the Dominion ironstone (4–13 m) is Arenigian. In the overlying Wabana Group (257 m) the Powers Step Formation (70 m) has a few beds of pyritic oolites in the basal 6 m; the Scotia Formation (2–4 m) of ironstones is Arenigian; the Grebes Nest Point Formation (18 m) has a thin ironstone of Arenigian in the upper part; the Gull Island Formation (0.5–3 m) of ironstones is Arenigian.

Major facies: A shallow sea.

The ironstones are enclosed in mudstone and sandstone.

The ooids consist of hematite, goethite, chamosite, siderite, and locally pyrite and phosphate.

Diagenetic effect: The hematite and goethite were formed from the earlier chamosite.

The average chemical composition (%): Fe_2O_3 68.7, FeO 10.0, SiO_2 9.9, Al_2O_3 3.2, CaO 2.4, MgO 0.4, P_2O_5 2.3, TiO_2 0.4.

Ref.: Maynard, 1983; Ranger et al., 1984.

49 – Grand Mira ooidal ironstone

Near Grand Mira and Marian Bridge in eastern Cape Breton Island, northeastern Nova Scotia. In folded and faulted metamorphic strata. An uneconomic deposit.

Age: Early Ordovician.

The ironstone is from a few to several cm thick in sandstone and slate. The ooids are hematite and magnetite.

Ref.: Wright, 1975.

50 – Doctors Brook and other ooidal ironstones

Near Doctors Brook and Arisaig in northern Antigonish County, and near Egerton in Pictou County, northwest Nova Scotia. In folded metamorphic strata. Abandoned mines.

Age: Early Ordovician. In the Ferrona Formation of the Iron Brook Group.

Major facies: A shallow marine setting.

The three ironstones are 0.5 to 2.5 m thick, in sandstone and tuffite.

Chemical composition (%): Fe 41–53, SiO_2 12–24, Al_2O_3 6–7, CaO 1–3.9, MgO 0.12–0.72, P_2O_5 0.48–1.23.

Ref.: Wright, 1975; Murphy et al., 1980.

Middle Ordovician

51 – Ooidal ironstones

In southeast Saskatchewan and southern Manitoba west of the Transcontinental (Sioux) Arch. In horizontal strata. Uneconomic deposits.

Age: Middle Ordovician. In Winnipeg, Black Island and Deer Island formations.

Major facies: A marine offshore shelf.

Most of the ooids are hematite or goethite; some of them are pyrite.

Ref.: Binda and Simpson, 1989; Witzke, 1980.

Late Ordovician

52 – Ooidal ironstone

In a borehole on the Grand Banks in the Atlantic Ocean, east of Newfoundland (47°00'N, 51°30'E). In folded strata. An uneconomic deposit.

Age: Late Ordovician.

Major facies: A marine offshore shelf.

Ref.: King et al., 1986.

Silurian

53 – Ooidal ironstone

Near Jacksontown and near Woodstock on the Saint John River in southern Carleton County, west-central New Brunswick. In folded strata. Abandoned mines and outcrops.

Age: Early-Middle Silurian.

Ref.: Bailey, 1898 (p. 13).

54 – Arisaig Brook and other ooidal ironstones

Near Arisaig in northern Antigonish County, and in the vicinity of Bridgeville-Sunnybrae in Pictou County, northern Nova Scotia. In folded stata. Uneconomic deposits.

Age: Middle Silurian. Near the base of the McAdam Formation.

Major facies: A shallow sea.The ironstones are 50 to 75 cm thick in sandstone and slate.

Chemical composition (%): Fe 35–46, SiO_2 17–23, Al_2O_3 4.8–7, CaO 1–11, MgO 0.2–0.4, P_2O_5 0.7–0.85.

Ref.: Wright, 1975.

Early Devonian

55 – Torbrook ooidal ironstones

Near Torbrook and Nictaux in the Annapolis Valley, in eastern Annapolis County, central Nova Scotia. In folded metamorphic strata. Abandoned mines.

Age: Early Devonian: Pragian (Siegenian) to Emsian. In Torbrook Formation of slate, phyllite, and quartzite.

Major facies: A shallow marine shelf.

The principal two ironstones are 1.5 to almost 3 m thick. The ooids are hematite, chamosite or greenalite, magnetite, and siderite.

Diagenetic effect: Late effect has produced magnetite and greenalite.

Chemical composition (%): Fe 40–49, MnO 0.74, SiO_2 15–16, Al_2O_3 4.4–4.8, CaO 2.9–6.7, MgO 0.52–0.67, P_2O_5 0.75–1.56.

Ref.: Wright, 1975.

Late Triassic

56 – Ooidal ironstone

In the western area of the Sverdrup Basin between Heiberg and Prince Patrick islands, Canadian Arctic Archipelago. In outcrops and boreholes. In horizontal and folded strata. An uneconomic deposit.

Age: Late Triassic. In Late Karnian Jenness mudstone and in Norian basal Barrow mudstone.

Major facies: A marine offshore shelf.

Ref.: Embry, 1982.

Jurassic

57 – Ooidal ironstones

In the western area of the Sverdrup Basin between Heiberg and Prince Patrick islands, Canadian Arctic Archipelago. In outcrops and boreholes. In horizontal and folded strata. Uneconomic deposits.

Age: Latest Triassic, Early, Middle and Late Jurassic. In Rhaetian-Hettangian basal Grosnevir Island mudstone, in Sinemurian basal Lougheed Island mudstone, in Pliensbachian basal Jameson Bay mudstone, in late Toarcian-Aalenian upper Jameson Bay mudstone, in Bajocian McConnell Island Formation, in early Bathonian lower Hiccles Cove Formation, and in Oxfordian Ringness Formation.

Major facies: A marine prodelta to offshore shelf in transgressive beds in fourth-order sequences.

The ironstones commonly occur with glauconite, and some are burrowed.

Ref.: Embry, 1982; 1993; Embry and Johannessen, 1993; Embry and Suneby, 1994.

58 – Ooidal ironstones

In the northern Ogilvie Mountains south of the Arctic Circle and north of Dawson, in northern Yukon Territory, northwest Canada. In folded strata. Uneconomic deposits.

Age: Early and Middle Jurassic. In Hettangian basal Kingak sandstone; in Pliensbachian Kingak mudstone; in Aalenian Kingak mudstone; and in Bathonian Kingak mudstone.

Major facies: A marine nearshore to offshore shelf.The ooids in the basal ironstone consist of ferric oxide and chamosite.

Ref.: Poulton, 1984.

59 – Ooidal ironstone

In the southeastern area 15 to 20 km south of Blairmore, western Alberta. In folded strata. An uneconomic deposit.

Age: Late Jurassic (Early Oxfordian). In the Fernie Formation, in the Green Beds of sandstone and siltstone overlying the Callovian Ribbon Creek Shale.

Major facies: A marine shallow shelf partially starved of sediment.

The Green Beds are condensed facies. The ooids? are composed of berthierine.

Ref.: Stronach, 1984.

Early Cretaceous

60 – Ooidal ironstones

In the eastern area of the Rocky Mountain foothills of northwestern Alberta. In nearly horizontal strata. Uneconomic deposits.

Age: Early Cretaceous. In Early Albian Bluesky Formation below and the Middle Albian Cadotte Member of the Boulder Creek Formation above the Spirit River and Hulcross formations of mudstone.

Major facies: A shallow marine shelf.

Ref.: Stott, 1982.

Late Cretaceous

61 – Ooidal ironstone

In the eastern area of the Rocky Mountain foothills of the northern Alberta. In nearly horizontal strata. An uneconomic deposit.

Age: Late Cretaceous – latest Cenomanian or early Turonian. In the lower member of Kaskapau Formation, overlying the sandy Dunvegan Formation and below the sandy Cardium Formation.

Major facies: A marine shelf.

The ironstone is about 1.5 m thick.

Ref.: Stott, 1967; Plint et al., 1993.

62 – Clear Hills ooidal ironstone

In the southern vicinity of Clear Hills and along the Rambling (Swift) Creek, near Grand Prairie along the Peace River, northwest Alberta. In horizontal strata. Has future potential.

Age: Late Cretaceous (Early Santonian). In the Badheart Formation above the Muskiki or Marshybank Formation and below the Puskwaskau Formation of mudstone.

Major facies: A shallow marine shelf.

The cross-bedded ironstone is about 5 m thick at the top of a coarsening upward sequence. The ooids consist of goethite set in nontronite. The Fe content in ooids is about 37 %.

Diagenetic effect: Ooids of green clay were changed to goethite and nontronite, and siderite and chalcedony were added to the cement.

Chemical composition (%): Fe_2O_3 30–43, FeO 6–13, MnO 0.12–0.18, SiO_2 24–26, Al_2O_3 4.8–5.9, CaO 1.3–1.7, MgO 1.1–1.5, P_2O_5 1.57–1.68, TiO_2 0.13–0.19.

Ref.: W. S. Donaldson. Petruk, 1977; Mellon, 1962; Plint et al., 1993.

China

Ordovician

63 – Hua-Tan ooidal ironstones

In southwestern Sichuan in Ning-Nan County, between Kichang and Kunming. About 190 km northeast-southwest and 40–50 km wide. A future potential ore.

Age: In lower part of middle Ordovician. As interbeds of limestone and clayey limestone.

Major facies: In a closed shallow bay.

Several beds of ironstones range from a few cm to several m thick, with 10 to 80 per cent ooids.

Ooids are goethite, hematite, and chamosite in various amount, but the chamosite decreases toward the outer rim.

An upper ironstone contains (%): Fe_2O_3 30–45, SiO_2 1.9, Al_2O_3 38, CaO 7, and MgO 1.99. A lower bed has 20–30 % Fe_2O_3.

Ref.: S-f. Liao. Liao, 1964.

64 – Fenhsi ooidal ironstone

In southwestern Shanxi Province about 150 km southwest of Taiyuan. In folded sedimentary rocks. An abandoned mine.

Age: Ordovician. Ironstone in shale, sandstone and limestone.

Major facies: In shallow marine environment.

Ooids contain magnetite, hematite, and goethite.

Ref.: Laznicka, 1981.

65 – Yangchuan ooidal ironstone

In eastern Shanxi Province about 100 km east of Taiyuan. In folded sedimentary rocks. An abandoned mine.

Age: Ordovician. Ironstone in shale, sandstone and limestone.

Major facies: In shallow marine deposits.

Ooids contain hematite and goethite.

Ref.: Laznicka, 1981.

Middle Devonian

66 – Ooidal ironstones

In central Yunnan Province, in eastern Yunnan-western Guizhou Provinces, in southeastern Guizhou Province, in northern Guangxi Province, and in central Sichuan Province. A future potential ore, except the Sichuan ooidal ironstone which is an uneconomic deposit.

Age: In the lower part of the middle Devonian. The ironstones are 5–10 km long and 3–5 km wide. In sandstone and sandy shale surrounded by limestone.

Major facies: In a nearshore sea.

Ooidal ironstones generally are as much as 2 m thick and rarely to 6–8 m thick. There are up to 10 beds of ooidal ironstones. Ooids are mainly hematite. The thickest ironstone beds have as much as 40–45 % Fe_2O_3.

Ref.: S-f. Liao. Liao, 1964.

Late Devonian

67 – Ooidal ironstones

In southern Hunan Province, in Hunan-Jiangxi provinces, and in Hunan-Jiangxi-Sichuan provinces. Ooidal ironstones 3–17 km long and 1–10 km wide. A future potential ore.

Age: Late Devonian. In clayey limestone and shale.

Major facies: Nearly closed shallow sea.

Three to five ironstone beds as much as 2 m thick and mainly of hematite, chamosite, and siderite with Fe_2O_3 as much as 40 %.

Ref.: S-f. Liao. Liao, 1964.

Early Jurassic

68 – Ji-Jiang ooidal ironstone

In southeastern Sichuan-northwestern Guizhou provinces, largely around Changsing. Mining is abandoned.

Age: Early Jurassic. In sandstone and clayey limestone.

Major facies: In a lacustrine section. Ironstones are in 1–2 m thick beds and the ooids are hematite, hematite-siderite and green clay mineral.

Ref.: S-f. Liao. Cheng Yugi et al., 1995.

Middle Jurassic

69 – Ooidal ironstone

In northeastern Sichuan-western Hubei provinces. An uneconomic deposit.

Age: Middle Jurassic.

Conditions are the same as the Early Jurassic ooidal ironstone.

Ref.: S-f. Liao. Cheng Yugi et al., 1995.

Colombia

Early Cretaceous

70 – Rio Luisa ooidal ironstone

Near El Valle and Tolima south of Payande on the west slope of Central Cordillera north of Ibaque, central Colombia. In folded strata. An uneconomic deposit.

Age: Early Cretaceous (Aptian).

Ref.: H. Duque-Caro.

Late Cretaceous

71 – Ooidal ironstone

On the west slope of the Central Cordillera north of Ibaque, central Colombia. In folded strata. An uneconomic deposit.

Age: Late Cretaceous (Cenomanian-Turonian).

Ref.: H. Duque-Caro.

Paleogene

72 – Socha ooidal ironstone

Near Paz de Rio east of Bucaramanga in the central part of the Eastern Cordillera, northeastern Colombia. In folded and faulted strata. An uneconomic deposit.

Age: Late Paleocene.

Major facies: A dominantly nonmarine alluvial setting. The ooids are goethite with minor berthierine.

Ref.: Ulloa, 1978.

73 – Paz de Rio ooidal ironstones

In the vicinity of Paz de Rio east of Bucaramanga in the central part of the eastern Cordillera, northeastern Colombia. In folded and faulted strata. In boreholes and outcrops. Currently exploited.

Age: Late Eocene. Near the base of the Concentracion Formation 1400 m thick of sandstone and mudstone.

Major facies: An inland sea.

The ironstone 0.5 to 8 m thick is enclosed in sandstone, and underlain and overlain by mudstone. Several thin ironstones lie 700 m higher in the Concentracion Formation. Equivalent ironstone lies 128 km to the south of Paz de Rio and 4 km east of Sabanalargo.

The ironstone is cross-bedded, burrowed, and contains fossil wood. The ooids consist of hematite, goethite, chamosite or berthierine, siderite, and pyrite.

Average chemical composition (%): Fe 35, MnO 0.17, SiO_2 24, Al_2O_3 3.8, CaO 7.7, MgO 2.5, P_2O_5 0.94.

Ref.: Kimberley, 1980; Ulloa, 1978.

Neogene

74 – Guayabo ooidal ironstones

In the southwest Maracaibo Basin, in the vicinity of Cucuta on the east flank of the eastern Cordillera, northeast Colombia. In folded strata. Uneconomic deposits.

Age: Late Miocene. Mostly in the lower half of the Cornejo Formation in the eastern part of the area and in the upper half in the western part. A few ironstones occur in the overlying lower Urimaco Formation.

Major facies: In a clastic deltaic complex of a shallow sea in a foreland basin.

The ironstones are 1 to 20 cm thick. The ooids are goethite and berthierine with nuclei of quartz grains or structureless goethite or green clay or faecal pellets. One kind of ironstones is largely goethitic and better sorted. The other kind is largely berthierine and ooids are elliptical to plastically deformed.

Ref.: James and Van Houten, 1979.

Czech Republic

Early Ordovician

75 – Ejpovice ooidal ironstone

Southwestern Bohemia, 10 km east of Plzeň. Lenses of hematite ooidal ironstone mostly at the base of Klabava Formation, transgressing the Precambrian. Ironstones enriched in rudaceous to argillaceous material occur in local depressions in the Precambrian floor, either directly upon the Precambrian or more frequently above the basal ferruginous conglomerate and sandstone. The overlying tuffs or

tuffitic claystones also enclose thin layers of hematitic ooidal ironstone. Uneconomic.
Age: Early Ordovician (Arenigian).
Ref.: Petránek, 1964c.

Middle Ordovician

76 – Ejpovice ooidal ironstone

Southwestern Bohemia, 10 km east of Plzeň. The length of the ironstone is 6 km, the width is at maximum 2 km, but the compact ironstone lens is only about 700 m wide; maximum thickness is 25 m. In the northwest, near the former coast, the ironstone lens represents the entire Šárka Formation; toward southeast (basinward) the ironstone becomes low-grade and disappears by interfingering with black shale the thickness of which is rapidly increasing. The ironstone is underlain by volcanic tuffs and overlain by black shales followed by quartzose sandstone; only locally the quartzose sandstone forms the roof of the ironstone. Low-dipping, faulted. Mining ended in 1967.

Age: Middle Ordovician (Llanvirnian).

Major facies: A marine shoreline setting during a transgressive episode. Part of a 40 km long ironstone horizon (Březina, Rač, Bechlov, Krušná hora, Velíz and other deposits).

Distribution of ore types shows a notable zoning: near the base are hematite ores, which are the richest ones, and they are transitional to black shales in the roof or basinward through mottled ores to sideritic ores with sparse spastolithic illite ooids.

Main minerals: hematite, berthierine, and illite form both ooids and matrix, siderite impregnates the matrix and partly replaces ooids. Some pyrite, phosphorite, clastic quartz.

Diagenetic processes include marked early reduction of trivalent iron, sideritization, phosphatization, pyritization, and supergene oxidation of siderite.

Chemical composition (%): In average Fe 26.20, Mn 0.24, SiO_2 27.31, Al_2O_3 9–11, CaO about 2, MgO about 2, P 0.48.

Ref.: J. Petránek. Kukal, 1962; Petránek, 1964c.

77 – Březina ooidal ironstone

Southwestern Bohemia, 17 km northeast of Plzeň. Isolated down-faulted block. Sharp contact with underlying tuffs and claystones (locally with Cambrian volcanics) and with overlying quartzite and sandstone. Basinward the ironstone is thinning and transitional into thicker argillaceous sediments. Mining ended in the 1870s.

Age: Middle Ordovician (Llanvirnian).

Major facies: Shallow marine embayment sheltered against influx of coarser clatics; ferruginous material is reworked and sorted. Ooids are hematite, siderite, bertherine, illite, and kaolinite. Phosphorite and pyrite also present. In addition to hematite and siderite ore the mottled ore, consisting of clusters of hematite ooids enclosed in clayey-sideritic matrix, is also common.

Diagenetic minerals: Siderite, berthierine, some hematite resultant from oxidation of siderite, nodules of phosphorite and pyrite.

Chemical composition: Siderite ores 23–26 % Fe, hematite ores 32–35 % Fe.

Ref.: J. Petránek. Skoček, 1963a.

78 – Rač (Radeč) and Bechlov ooidal ironstones

Southwestern Bohemia, 10–13 km north-northeast of Rokycany. Ironstone occurs in isolated down-faulted blocks (Rač deposit is part of the same block as the Březina ironstone). Mining ended in the 19th century.

Age: Middle Ordovician (Llanvirnian).

Major facies: Marine, shallow-water ironstone with rapid changes of quality and numerous heterogeneous intercalations. In Rač area the ironstone is overlying diabase tuffs and is overlain by argillaceous shale passing upward into quartzose sandstone. In Bechlov the ironstone is transgressively overlying Early Tremadocian and locally Precambrian rocks, and is overlain by quartzose sandstone.

The most common ore type is argillaceous siderite with illite and kaolinite ooids. Some siderite ironstones are rich in berthierine (ooids and matrix), hematite ironstones are less common. Interbeds in ironstone are sandstone, siltstone, conglomerate, mudstone and tuff. Conglomerates usually occur at the base of the ironstone. In the Rač area the sandstone and siltstone form an interbed in the center of the ironstone.

Diagenetic features: Recrystallization and redistribution of siderite, some oxidation (hematite formation), berthierine cement, phosphorite, pyrite.

Chemical composition: The ironstone contains 20–30 % Fe and the iron content is gradually decreasing basinward.

In the Rač area nodular to massive siderite with scarce illite ooids occurs at the base of the Llandeilian Dobrotivá Formation (mudstone), similar siderite occurs in Llandeilian quartzose sandstone in the Bechlov area.

Ref.: J. Petránek. Skoček, 1963b.

79 – Mníšek ooidal ironstone

Central Bohemia, 26 km southwest of Prague. Ironstone ("Main Deposit") is underlain and overlain by black shale, but locally may transgressively overlie Cambrian (a submarine swell). The "Roof Deposit" is in roof of the shale and is overlain by quartzose sandstone. The shales below the Main Deposit contain several thin ironstone lenses. The ironstone is folded and faulted and is situated within a major brachysyncline. The ironstone lens is 1.5 km long, the preserved width 160 m, the thickness in the center is 10–12 m. Mining ended in 1966.

Age: Early Ordovician (Llanvirnian).

Major facies: Shallow-water sediment laid down in a depression partly isolated from the main basin. Reworking and redistribution of ooids. Main minerals are siderite, hematite, illite, berthierine, phosphorite.

Diagenetic processes: reduction of trivalent iron, sideritization, silicification and pyritization.

Average chemical composition (%): Fe 30.29, SiO_2 23.91,

$CaO+MgO$ 1.2–4.3, Al_2O_3 6.30–12.10, P_2O_5 0.6–2.1.
Ref.: Petránek, 1975.

80 – Krušná hora ooidal ironstone

Central Bohemia, 8 km west of Beroun. The Main Deposit, underlain by basalt tuffs (Arenigian), is split by basalt flow into the Large Deposit (4–5 m to about 20 m thick) and the overlying Small Deposit (up to 2.5 m). In its roof are mainly basalt pyroclastics, grading rapidly into black shales with sandy intercalations. The uppermost shales are transitional into a deposit of argillaceous siderite (up to 10–12 m thick), overlain by Llandeilian quartzose sandstone. Faulted syncline, isolated within Precambrian. Mined until 1967.

Age: Early Ordovician (Llanvirnian).

Major facies: Ironstone formed not far from the coast during the Llanvirnian transgressive episode. The ooids were reworked and redeposited in a local depression, partly isolated from the open sea and possibly influenced by synsedimentary tectonics.

Main minerals are hematite, siderite, illite, clastic quartz, phosphatic brachiopod shells (detritus) and diagenetic phosphorite, pyrite and quartz. Ooids are hematite and illite.

Average chemical composition (%) of the Large Deposit: Fe 28.62, SiO_2 27.75, Al_2O_3 11.24–14.71, CaO 1.55–2.90, MgO 1.48–1.88, P 0.28–0.38, S 0.12; Small Deposit: Fe 35.32 and SiO_2 22.11. Deposit of argillaceous siderite at the top of Llanvirnian sequence: Fe 26.28, SiO_2 23.05, Al_2O_3 8.31, CaO 3.02, MgO 2.00, P 0.30, S 0.17.

Ref.: Petránek, 1974.

81 – Velíz ooidal ironstone

Central Bohemia, northwest of Zdice. Steep Ordovician syncline down-faulted into Precambrian. Ironstone is 0.2 to 15 m thick (in the center of the syncline about 6 m) and is underlain by tuffs and overlain by basalt flow or dark gray shales. Prospection activities in the past. Uneconomic.

Age: Middle Ordovician (Llanvirnian).

Major facies: Ironstone accumulated in local depressions not far from the coast. Hematite ironstone forms usually the lower part of the ore body, the upper is sideritic; sideritic ore may also occur in the middle of the hematitic ore body. Main minerals are hematite (ooids and matrix), siderite, illite (matrix, some ooids), berthierine (ooids, some matrix).

Chemical composition (%): Siderite ore Fe 19–24, SiO_2 33–38, hematite ore up to 29.5 Fe, up to 28.5 SiO_2 (locally 33–35 Fe, 33–38 SiO_2). Average contents Al_2O_3 12.65, CaO 2.82, MgO 2.03 and P_2O_5 1.38.

Ref.: Petránek, 1972.

82 – Komárov ooidal ironstone

Central Bohemia, 21 km east-northeast of Rokycany. Numerous ironstone lenses of restricted extent and in different stratigraphic positions mostly occur within a thick series of basic tuffs and tuffites, basalt flows, granulates, and agglomerates. The Lower Deposit (group of lenses) is 4–5 m, the Main Deposit 9–24 m, and the Upper Deposit 7–9 m thick. An ironstone lens locally also occurs at the contact of the volcanic series with the overlying mudstone and shale. Synclinal structure, faulted. Mining (including tuffs and agglomerates impregnated by hematite) ended in the 19th century.

Age: Middle Ordovician (Llanvirnian).

Major facies: The rather variable stratigraphic position and the small size of ironstone lenses are indicative of deposition in small local depressions, e.g. between pyroclastic accumulations or lava flows. Strong evidence of wear and redeposition of ooids. Main minerals are hematite, siderite, berthierine, illite and quartz. Ooids are hematite, berthierine and illite.

Diagenesis: Reduction of the trivalent iron, sideritization, cementation by berthierine, silicification of ooids.

Chemical composition (%): Fe 21–34, SiO_2 23–52, Al_2O_3 5.5–12.6, P_2O_5 0.18–1.15.

Siderite to argillaceous siderite with infrequent ooids occur at the contact of mudstone with overlying quartzose sandstone.

Ref.: Petránek, 1975.

Late Ordovician

83 – Nučice-Chrustenice ooidal ironstone

Central Bohemia, southwest of Prague, between Prague and Beroun. Significant ore horizon traceable for about 65 km; it comprises the Nučice-Chrustenice lens (in northeast), the Zdice lens and the Chlustina lens (in the SW) but mostly consists of sideritic black shale conspicuously enriched in phosphorite and pyrite. Economically most important had been the Nučice-Chrustenice lens, 8.6 km long and up to 20 m thick. It is underlain by sandstone with shaly partings and is transitional to a black claystone in the roof. Folded and faulted. Mined since 4th century BC until 1965.

Age: Late Ordovician (approx. middle part of Caradocian).

Major facies: Deposited farther from the coast, on a side of a submarine swell, at the beginning of a transgressive episode.

Ooids as well as matrix usually consist of berthierine, partly replaced by siderite, less frequently by magnetite (in the central parts of ore lens). Siderite cement is common, other constituents are illite and kaolinite (both forming ooids and matrix), phosphorite, pyrite, rare hematite. Clastic quartz mainly in the margins of the lens together with spastolithic illite ooids. Some organic matter present. Multiple ooids are rare. The ironstone material is well sorted and is indicative of redeposition.

Diagenetic processes deeply affected the original ferruginous material – resulted in magnetitization and widespread sideritization, in neoformation of other carbonates, phyllosilicates (berthierine cement), apatite, pyrite and quartzine.

Chemical composition (%): Fe 25–42, SiO_2 5–22, Al_2O_3 3.5–10, CaO 1.5–6, MgO 1–3, P 0.8–1.7, S 0.2–1.6.

Ref.: Petránek et al., 1988.

84 – Zdice ooidal ironstone

Central Bohemia, about 6 km southwest of Beroun. The folded and faulted ironstone is underlain by black shales overlying sandstone, and overlain by black claystone. The ironstone lens is 5.4 km long, 700–800 m wide and up to 10 m thick; about 50 m above it there is another ironstone lens (thin, low-grade).

Age: Late Ordovician (approx. middle part of Caradocian). Ironstone belongs to the significant Nučice ore horizon. Farther to the southwest (13 km SW of Beroun) is the 5 km long Chlustina ironstone lens (overlying sandstone and mudstone and underlying black shale), stratigraphically corresponding to the Zdice ironstone.

Major facies: Deposited near the coast, close to submarine swell and coinciding with the beginning of a transgressive episode.

Sideritic ores with siderite and illite as main minerals. Illite ooids enclosed in siderite matrix are frequently spastolithic and partly replaced by diagenetic siderite.

Chemical composition (%): Fe 28–33, Mn 0.25–0.65, SiO_2 11.5–19, Al_2O_3 4,6–8.9, P 0.49–1,40.

Ref.: J. Petránek. Röhlich, 1955, Svoboda and Prantl, 1955.

85 – Karlík ore horizon

Central Bohemia. Traceable for about 50 km from east of Prague to Zdice in southwest. Underlain by Zahořany dark gray mudstone and overlain by Bohdalec black claystone. Argillaceous carbonates, partly siderite, rich in phosphorite and pyrite, with clusters of kaolinite ooids (some are pyritized or sideritized); thickness 1–1.5 m, locally about 12 m.

Age: Late Ordovician (Late Caradocian)

Ref.: J. Petránek, Chlupáč et al., 1992; Petránek, 1965; Röhlich, 1957.

86 – Podolí ore horizon

Central Bohemia, southwest to east of Prague, traceable for about 25 km. At the contact between the underlying black and overlying greygreen claystones. Argillaceous siderite or concretions, at places only carbonatic shales, with few kaolinite ooids, with pyrite and abundant phosphorite. At maximum a few meters thick.

Age: Late Ordovician (boundary Caradocian/Ashgillian).

Ref.: J. Petránek. Petránek, 1965; Röhlich, 1957.

Early Devonian

87 – Bubovice ooidal ironstone

Bubovice, 24 km southwest of Prague, outcrop in Stydlé vody Quarry. The ironstone is 5–35 cm thick. Uneconomic occurrence.

Age: Early Devonian (Pragian), Řeporyje Limestone Member.

Major facies: Shallow marine setting. The poorly sorted ironstone is related to a local regressional episode. It is a mixture of fragments of ironstone (crusts) and limestone, ferruginous pisoids (up to 40 mm) and ooids, and abundant bioclasts. Ironstone shows an erosional base and is enclosed in reddish or gray nodular limestone. Ooids and pisoids consist of hematite with subordinate green clay mineral.

Diagenetic effect: Secondary calcite impregnation and conversion of green clay mineral into hematite.

Chemical composition (%): Fe^{3+} 25.5–34.5, Fe^{2+} 0.5–4.5, SiO_2 10.7–17.0, Al_2O_3 3.5–6.4, P_2O_5 0.3–1.0.

Ref.: J. Petránek. Skoček and Kukal, in print.

Late Devonian

88 – V Habeši ooidal ironstone

Quarry in the city of Brno, Moravia. In folded strata. An uneconomic deposit.

Age: Late Devonian (late Frasnian). In the uppermost part of Vilémovice Limestone Member of the Macocha Formation.

Major facies: A marine shoreline (backreef) during retrograding (stagnation) in a foreland basin. The ironstone is set in a carbonate sequence with carbonates below and above it.

The maximum thickness of ironstone is 15 cm. Ooids consist of hematite or goethite, and siderite. Matrix is quartz silt and carbonate cement.

Average chemical composition (%): Fe_2O_3 2.4–6.3, FeO 0.14–0.9, SiO_2 18–46, Al_2O_3 12–30, CaO 1–9, MgO 1.1–3.8, P_2O_5 0.04–0.15, TiO_2 0.3–1.2.

Ref.: J. Dvořák. Dvořák et al., 1986; Skácel, 1953.

Early Carboniferous

89 – Uhřice ooidal ironstone

Borehole 60 km east of Brno, Moravia. In horizontal strata. An uneconomic deposit.

Age: Early Carboniferous (Late Visean). At the base of the Myslejovice Formation. The ironstone is underlain by Famennian and overlain by Late Visean strata.

Major facies: A marine shoreline setting during local prograding in a foreland basin.

The ironstone is underlain and overlain by limestone.

The ooids and minor pisoids (to 4 mm) are both unaltered and altered. They consist mainly of hematite, goethite, and chamosite, with minor siderite and sulfide. The matrix includes kaolinite, volcanic quartz and feldspar, fragments of acid volcanic rocks, and plutonic quartz.

Diagenetic effect: Early sideritization, pyritization, and silicification.

Average iron content is 16.8 %.

Ref.: L. Maštera.

Denmark

Paleogene

90 – Oksenrade ooidal ironstone

Near Middelfart in Fyn Province, eastern Denmark. In gently folded strata. Un uneconomic deposit.

Age: Late Oligocene (Chattian). In the uppermost part of the Vejle Fjord Formation.

Major facies: A locally prograding marine setting in a cratonic interior.

The ironstone is in the coarsening upward siliciclatic (mostly quartz) strata with glauconite. It is less than 2 m thick.

The rare ooids are weathered. They consist of glauconite, siderite, and goethite.

Diagenetic effect: Glauconite was changed to goethite and siderite.

Average chemical composition (%): Fe 34, Mn 0.34, SiO_2 25, Al_2O_3 8.14, CaO 1.32, MgO 1.75, P 0.26, Ti 0.14.

Ref.: E. S. Rasmussen. Neumann-Redlin and Zitzmann, 1977/1978a.

Egypt

Late Cretaceous

91 – Ooidal ironstones

In the middle and southern part of the Bahariya Oasis 175 km west of the Nile River and in Wadi Qena 175 km east of the Nile River about 275 km south of Cairo, and in Jebel Gharamul in the Gulf of Suez lowland 300 km southeast of Cairo, central and east-central Egypt. In horizontal or gently folded strata. Uneconomic deposits.

Age: Late Cretaceous (Late Cenomanian-Turonian). In the Heiz Formation in the Bahariya and Wadi Qena area, and in the correlative Galala Formation in the Gulf of Suez lowland.

Major facies: A nearshore transgressive sea in a cratonic interior.

The ironstones are lenses 5 to 15 cm thick in a fine-grained sandstone, mudstone and marlstone. In the Bahariya ironstones the ooids and peloids are commonly distorted. In the northern part of Bahariya Oasis there are local beds of glauconite.

The ooids and peloids in the Bahariya Oasis are hematite, goethite, "chamosite", and kaolinite.

Ref.: I. M. I. El-Mansey. Van Houten et al., 1984.

92 – Aswan ooidal ironstone

In the east and west sides of the Nile River at Aswan, about 275 km south of Cairo in southeastern Egypt. In horizontal strata. Abandoned mines.

Age: Late Cretaceous (Turonian to Coniacian). In the sandstone and mudstone Nubia Formation which lies on Precambrian rocks.

Major facies: A shallow marine embayment in a cratonic interior.

The three ironstones are each above shoaling upward claystone and cross-bedded and burrowed fine-grained sandstone. The lowest ironstone is about 10 to 20 cm thick; the middle one is up to 2 m thick; the upper one is a multiple ironstone of several beds of 5 to 80 cm in thickness. Most of the ooids have peloidal nuclei. Some of them are ellipsoids or spastoliths.

The ooids and peloids contain hematite, goethite, berthierine, and kaolinite.

Diagenetic effect: Berthierine was changed to goethite and hematite.

Average chemical composition of the ore (%): Fe_2O_3 53.67, FeO 2.63, SiO_2 17.67–18.5, Al_2O_3 5.18–6.06, CaO 4.33 to 7.82, MgO 1.38–1.49, MnO 0.51–2.35, P_2O_5 1.06 to 1.80.

Ref.: D. P. Bhattacharyya. Bhattacharyya, 1980; 1989; Germann et al., 1987.

Estonia

Middle Ordovician

93 – Ooidal ironstone

In boreholes in Estonia.

Age: Middle Ordovician, as in Östergötland in southeast-central Sweden.

France

Early Ordovician

94 – Ooidal ironstones in the Basin of Bretagne-Anjou

Along the cities of Angers-Segré-Chateau in Brittany, northwest France. In folded and faulted strata. Abandoned mines.

Age: Early Ordovician (Arenigian). In the top of the Gres Armoricain Inférieur Member.

Major facies: Barrier bar and storm deposits in regional transgression in a passive margin.The four cross-bedded ironstones lie above quartz arenite and below siltstone in a transitional contact. Each is several meters thick, spread through more than 150 m of Gres Armoricain Inférieur Member.

The ooids consist of hematite, chamosite, magnetite, and maghemite, with minor apatite, pyrite, and siderite.

The diagenetic effect: Berthierine was changed to chamosite, magnetite, pyrite, and siderite.

The average chemical composition (%): Fe 36, SiO_2 28, Al_2O_3 6.7.

Ref.: J. J. Chauvel. Chauvel, 1974; Joseph, 1982.

Middle Ordovician

95 – Ooidal ironstones in Crozon and in Normandy basin

In the vicinity of Crozon in Brittany and the region of Domfront-Caen in Normandy, northwest France. In folded and faulted strata. In abandoned or uneconomic mines and outcrops.

Age: Early Middle Ordovician (Llanvirnian). In the Postolonnec Formation in Crozon area in Brittany, and the top of the Urville Formation in Normandy.

Major Facies: A barrier bar setting during regional transgression in a passive margin (Normandy).

The commonly cross-bedded and burrowed ironstones are underlain by sandstone and overlain by shale. They are a few cm thick in Crozon and as much as 10 m in Normandy where the lower part mainly contains hematite and the upper part chamosite and siderite.

The ooids are hematite, chamosite, and siderite, and minor apatite and magnetite.

Chemical composition of the average Normandy ironstones (%): Fe 35–40, SiO_2 6–15, Al_2O_3 3–9, CaO 1.5–3, MgO 0.5–2.

Ref.: J. J. Chauvel. Joseph, 1982; Young, 1989.

96 – Montflours ooidal ironstone

In Montflours near Laval in eastern Britany. In folded and faulted strata. Un uneconomic deposit.

Age: Late Middle Ordovician (Llandeilian). In 125 m Traveusot Formation above the Gres Armoricain Supérieur and below the Caradocian (Late Ordovician) sandstone.

Major facies: Marine setting.

The three ironstones (0.2, 0.8, and 1.2 m thick) are on tops of coarsening upward sequences in the Traveusot black shale. The unweathered ooids are composed of chamosite and siderite.

Ref.: J. J. Chauvel. Chauvel et al., 1970.

Late Ordovician

97 – Crozon and Saint-Sauveur-le-Vicomte ooidal ironstones

In Crozon in western Brittany and in Normandy, northwestern France. In folded and faulted rocks. Several uneconomic deposits.

Age: Early Late Ordovician (Caradocian). In the Veryac'h Formation at Crozon.

Major facies: A shallow sea.

The few to several cm thick ironstones are in black shale, in burrowed and coarsening upward sequence at Crozon.

The ooids are composed of chamosite, apatite, and siderite. The matrix has phosphatic intraclasts.

Ref.: J. J. Chauvel. Chauvel and Robardet, 1970. Young, 1989.

98 – Crozon ooidal ironstone

In Crozon in western Brittany. In folded and faulted strata. An uneconomic deposit.

Age: Late Ordovician (Ashgillian). At the base of the Rosan Formation of black shale.

Major facies: A shallow sea.A coarsening upward sequence has a 20–40 cm thick ironstone at the top.

The ooids are chamosite. The matrix has phosphatic intraclasts.

Ref.: J. J. Chauvel. Young, 1989.

Early Devonian

99 – Diélette and l'Hermitage-Lorge ooidal ironstones

In Diélette near Flamanville, and near Saint Brieue in Brittany, northwestern France. In folded and faulted rocks. Abandoned mines and outcrops.

Age: Late Early Devonian (Emsian). In schist and limestone of the metamorphosed Nehou Formation.

Major facies: A shallow sea.

There are as many as 4 layers of ironstones 2 to 6 m thick.

The ooids consist of hematite, chamosite, siderite, and magnetite. The matrix contains some garnets.

The average chemical composition (%): Fe 48–58, SiO_2 10–16, Al_2O_3 3.6, CaO 4–5.

Ref.: J. J. Chauvel. Horon, 1977/1978.

Middle Devonian

100 – Ooidal ironstone

In the region of Fourmies in the north of Ardennes, northeastern France. In folded and faulted strata. Several abandoned deposits.

Age: Early Middle Devonian (Eifelian).

The two ironstones are 1–1.25 m thick. The ooids are hematite, chamosite, and siderite.

Average chemical composition (%): Fe 34.86, SiO_2 18.5, Al_2O_3 11.29, CaO 4.25.

Ref.: Horon, 1977/1978.

Early Jurassic

101 – Morvan ooidal ironstone

Ironstone occurs north and east of Morvan (eastern France, west-southwest of Dijon).

Age: Early Jurassic (Hettangian).In the north the ironstone is 0.7–2m thick and contains 24–40 % Fe, 3–13 % SiO_2, and 30–50 % CaO; the mining ended in the 1870s. In the east the ironstone contained 25–28 % Fe, 0.15 % Mn, 0.45 % P, and 0.15 % S; the mining ended in 1921.

Ref.: Horon, 1977/1978.

102 – Ooidal ironstone of Verdun

In a borehole near Verdun (60 km west of Metz, northeastern France), at a depth of almost 600 m, ironstone of a thickness of 11 m occurs; its upper part contains 27 % Fe.

Age: Early Jurassic (Toarcian).

Ref.: Horon, 1977/1978.

103 – Ooidal ironstone of Alsace

Age: Early Jurassic (Toarcian).

Ironstone layers, strongly affected by faulting, are 2 to 12 m thick and contain 20–25 % Fe.

Ref.: Horon, 1977/1978.

104 – Jussey ooidal ironstone

Northeastern France, Haute Saone.

Age: Early Jurassic (Toarcian).

The ironstone layer is 6–7 m thick and contains approximately 27.5 % Fe, 18 % CaO and 9 % SiO_2.

Ref.: Horon, 1977/1978.

105 – Ooidal ironstones fringing the Jura Mts.

In eastern France, along the border of the Jura Mts., ironstones occur at numerous places (e.g. La Verpilliere). They usually form one or several layers of 1 m thickness.

Ref.: Horon, 1977/1978.

106 – Causse Comtal ooidal ironstone

Southern part of Massif Central (north of Rodez), southern France.

Age: Early Jurassic (Toarcian).

One or two ironstone layers of 1 to 5 m thickness contain about 25 % Fe.

Ref.: Horon, 1977/1978.

Early/Middle Jurassic

107 – Ooidal ironstones of Lorraine (Minette)

Northeastern France, northeastern margin of the Lias (Early Jurassic) Paris Basin. Ooidal ironstones extend for a distance of about 150 km from the Luxembourg border in the north to environs of Nancy in the south. The ooidal ironstone, called Minette, was laid down off the coastline of the Ardennes/Rhenish Massif island. The ironstones are faulted but flat lying and inclined 3 degrees toward the center of the Paris Basin. The strata are dissected by major faults trending SW-NE and split into several basins or subbasins. The ironstones principally occur in two subbasins, in the Esch-Ottange Subbasin and Differdange-Longwy Subbasin, mutually separated by the Audun-le-Tiche Fault; of lesser importance are the Orne and Nancy subbasins. Subsidence (brought out by the reactivating of structures of the underlying Variscan basement) resulted in formation of syndepositional troughs (synclinal zones); in these the ironstones are both of higher grade and greater thickness. They were extensively exploited until recently.

Age: The age of the ironstones ranges from Toarcian (latest Early Jurassic) to Aalenian (earliest Middle Jurassic).

Major facies: Shallow marine, near-shore sediments, mostly laid down in a high-energy environment, frequently as large-scale sand waves. The ooidal ironstones are cross-bedded.

The ironstone unit may be even more than 60 m thick and consists of individual coarsening-upward sequences. The Early Jurassic is formed by four coarsening-upward megasequences and the Minette ironstone occurs at the top of one of these cycles. Within the Aalenian sequence there are about 12 transgressive and regressive events. The thickest ironstones are found in syndepositional troughs, i.e. in the synclines.

The deposition of the ironstone had been preceded by that of bituminous paper shales followed by calcareous marls and finally by sandstones. The ironstone is overlain by conglomerate and sandstone the deposition of which was followed by that of marl.

There are 11 to 12 ironstone layers at maximum. They are being designated by letters or their color. At the base of Aalenian the ironstones are siliceous (ironstone layers Green, Black and Brown) and these are overlain by calcareous ironstones (ironstone layers Gray, Yellow and Red) which are more important economically. Usually no more than three layers were exploitable at a place.

The ooids mostly consist of goethite and/or hematite, berthierine and siderite. Goethite contains significant admixture of Al_2O_3 and has frequently been designated as limonite; some silica and phosphorus are also admixed to it. Other constituents are quartz, calcite, clay minerals, some magnetite and pyrite.

The clastic admixture of ironstone consists of quartz grains, argillaceous matter and fragments of skeletal parts of lamellibranchs and echinoderms. Whole fossils also occur.

Diagenesis: The most important diagenetic process has been the reduction of the originally trivalent iron which led to the destruction of the original nature of the ferruginous deposit and to the neoformation of siderite, berthierine, and pyrite. New transformation of the mineral constituents occurred upon exposure to the effects of superficial alteration. The reduced mineral components were oxidized and some minerals were dissolved and leached out.

Oxidized ooids usually contain about 50 % Fe unless the uncommon case when large quartz grains form nuclei of ooids.

Chemical composition varies in particular ironstone layers (%): Fe 31–37, Mn 0.02–0.13, SiO_2 6–16, Al_2O_3 4–7, CaO 5–19, MgO 1.3–2.3, P 0.08–1.13, S 0.08–0.23 and V about 0.2. The ore reserves are estimated at 8 billion tons.

Ref.: J. Petránek. Bubenicek, 1963; Horon, 1977/1978; Teyssen, 1989.

Middle Jurassic

108 – La Voulte ooidal ironstone

Southeastern France, south-southwest of Valence.

Age: Late Middle Jurassic (Callovian).

Limonitic marine ironstone with marly intercalations. The ironstone is several meters thick with 30–50 % Fe, 10–24 % SiO_2, 1–11 % CaO.

Ref.: Horon, 1977/1978.

Early Cretaceous

109 – Ooidal ironstones

Marine ooidal ironstones occur at numerous places in units of different Early Cretaceous age: Valanginian, Barremian (up to 2 m thick ironstone layers with a maximum of 43–47 % Fe) and Aptian (ironstone layers fringing Ardennes average 1 m in thickness, locally 2.5 to 3 m).

Ref.: Horon, 1977/1978.

Germany

Early to Late Ordovician

110 – Ooidal ironstones of central Thuringia

East-central Germany, central Thuringia, south-west of Saalfeld. Numerous occurrences. Ironstone lenses in an area about 25 km long, averaging 1.5 m in thickness (only locally considerably more). Folded and faulted. Mining (open pit and underground) ended in 1971.

Age: The lower ore horizon is at the Tremadocian/Arenigian boundary, the middle ore horizon is Arenigian and the upper ore horizon is at the Caradocian/Ashgillian limit.

Major facies: Three, relatively stable ironstone horizons. The lower one overlies thick Phycodes Quartzite Formation (up to 150 m thick in the Schwarzburger Sattel area) and has the Griffel Shale Formation in its roof; this argillaceous formation encloses the so-called middle ore horizon. The upper ore horizon is situated at the contact of the Griffel Shale Formation and the overlying Main Quartzite Formation. In this area, however, the quartzite is very thin or may even be missing and the ironstone is then overlain by the following Leder Shale Formation.

The ironstone lenses are relatively narrow (500–1,000 m) and up to several kilometers long; their shape is indicative of deposition in marine narrow lows and troughs.The lower ore horizon is usually less than 1 m thick and only locally can be thicker (Schmiedefeld). The chamositic ironstone contains fragments and pebbles of shale and quartzite. The middle ore horizon, when developed, has usually the form of ferruginous quartzite and only in places of swelling has the form of chamositic ooidal ironstone (Oberwirbach, Unterwirbach).

The upper ore horizon is of all three ore horizons most persistent and economically most important. In the Schmiedefeld and Wittmannsgereuth deposits the upper ore horizon attained the thickness of up to 25 m. In Schmiedefeld, in places of maximum swelling, quartzite intercalation appears within the ore lens.

The ooidal ironstones consist mainly of chamosite, siderite, and thuringite, contain in addition to abundant clastic quartz also some dolomite, phosphorite nodules and magnetite when affected by metamorphism. Worn fragments or pebbles of shale and quartzite also occur in the ironstone.

Diagenesis: Diagenetic origin can be ascribed to chamositic cement, very abundant siderite replacing the cement and some ooids, locally abundant pyrite replacing the ooids, phosphorite, little quartz, little magnetite, and thuringite resultant from late diagenetic or anchimetamorphic recrystallization.

Chemical composition of the Schmiedefeld and Wittmannsgereuth ores (%): Fe 32–34, Mn 0.7–2.1, SiO_2 20–22, Al_2O_3 11–12, CaO 2.5–3, MgO 2–2.5, P 0.3–0.9, S 0.25–0.5.

Ref.: J. Petránek, Bach et al., 1977/1978; Deubel, 1942; Hetzer, 1958.

111 – Ooidal ironstones of the Schleiz area

East-central Germany, eastern Thuringia, near Plauen.

Age: The lower ore horizon is at the Tremadocian/Arenigian boundary, the upper ore horizon at the Caradocian/Ashgillian boundary.

Major facies: Marine setting. Two relatively stable ironstone horizons. The lower one overlies a thin quartzite formation (Phycodes Quartzite) and in its roof is the Griffel Shale Formation. Above it the upper ore horizon is situated which is overlain by thick Main Quartzite Formation (even more than 100 m thick).

The lower ore horizon is usually 1 m thick or even less, only at some localities (e.g. Sparnberg, Triebes, Lauterbach) the ironstone lenses are swelling to greater thickness.

The upper ore horizon is usually not much thicker than 0.5 m, only in some places its thickness is greater.

The ooidal ore consists mainly of chamosite and siderite; oxidic ores are rare.

Diagenesis: Main effects are chamosite cementation, and sideritization affecting both cement and ooids.

Ref.: J. Petránek. Bach et al., 1977/1978; Deubel, 1942; Hetzer, 1957.

Early Jurassic

112 – Balingen ooidal ironstone

South-southwest of Stuttgart, Baden-Württemberg, southern Germany.

Age: Early Jurassic (Hettangian)

Major facies: Marine ooidal ironstones are marginal to the Vindelician land for tens of kilometers and are transitional into sandstone or conglomeratic sandstone, in the opposite direction into limestone.

Ref.: J. Petránek. Aldinger and Frank, 1942.

113 – Harzburg ooidal ironstone

Northern foreland of the Harz Mts., south of Braunschweig, north-central Germany. There are four ore beds separated by gray claystone (sometimes with some sand) which also underlies and overlies the group; prior to its deposition slight regression and emergence took place.

Three of the ore beds have a total thickness 9–11.5 m. Strongly folded (overturned strata) and faulted. Mining ended in 1963.

Marine deposition occurred between the basinal claystone and the near-coast sandstone facies.

Age: The Early Sinemurian ironstone is accompanied by Early Pliensbachian ooidal ironstone of lesser importance.

Main ore minerals are goethite, siderite and some "chamosite"; detrital ore is also present.

The main diagenetic minerals: Siderite, calcite, pyrite.

Chemical composition (%): Fe 27.8, Mn 0.16, SiO_2 12, Al_2O_3 7.5, CaO 16, P 0.48, S 0.28, Ti 0.13.

Ref.: J. Petránek. Simon, 1969.

114 – Badeleben-Sommerschenburg ooidal ironstone

Central Germany, about 25 km west of Magdeburg. Ironstone is of ooidal-detrital type, 10–20 m thick. Mining abandoned in the 1960s.

Age: Early Jurassic (Early Sinemurian).

Major facies: marine setting. Ironstone is enclosed in claystone in a transitional zone between the sandy and clayey facies parallel with the coast. Enrichment in narrow synsedimentary depressions.

The lower part of the deposit is mainly goethite, iron silicate and siderite; the upper part mainly ironsilicate (berthierine etc.), siderite, limonite, magnetite and pyrite.

Average chemical composition (%): Fe 24.5, SiO_2 47, Al_2O_3 8.5, CaO 2, MgO 1.8, P 0.4, S 0.05.

Other ooidal ironstones of Early Sinemurian age occur in Egge Mts. and Volkmarsen at the eastern border of the Rhenish Massif in west-central Germany.

Ref.: J. Petránek. Bach et al., 1977/1978; Neumann-Redlin et al., 1977/1978.

115 – Bislich ooidal ironstone

Northern border of the Rhenish Massif, on the lower Rhine, between Wesel and Xanten, western Germany. Ironstone is 2–8 m thick and extends for 8 km^2 in a syncline within a graben at a depth of several hundred meters.

Age: Early Jurassic (early Pliensbachian).

Major facies: The basal calcareous ironstone shows a transgressive contact with the underlying non-calcareous claystone. Ironstone body is laterally degraded and split by marlstone intercalations into three ore beds.

Main minerals are limonite with some "chamosite", siderite and pyrite. Siderite and pyrite are of diagenetic origin.

Chemical composition (%): Fe 25–30, Mn 0.2, SiO_2 10–14, Al_2O_3 7–13, CaO 10–15, P 0.45, S 0.35.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978; Thienhaus, 1969a.

116 – Echte ooidal ironstone

Western foreland of Harz Mts., central Germany. Two ironstone beds of 3–7 m combined thickness; inclined and faulted. The mining ended in 1962.

Age: Early Jurassic (early Pliensbachian).

Major facies: Marine. Ironstone overlies claystone with a sharp contact showing some erosional features. Maximum deposition is related to tectonically induced trap. Limestone is in the roof.

Main mineral constituents: Hematite-goethite, calcite, "chamosite" and siderite; of diagenetic origin is mainly siderite, pyrite and some calcite.

Chemical composition (%): Fe 25.1, Mn 0.14, SiO_2 13.4, Al_2O_3 8.7, CaO 18.2, P 0.5, S 0.2, Ti 0.16. The upper bed: up to 40–43 Fe.

Ref.: J. Petránek. Finkenwirth and Simon, 1969; Neumann-Redlin et al., 1977/1978.

117 – Lenglern ooidal ironstone

Western foreland of Harz Mts. (northwest of Göttingen), central Germany. Faulted horizontal strata; the ironstone bed is 2–7 m thick and its length in the subsurface is over 800 m. Open-pit mining ended in 1961.

Age: Early Jurassic (early Pliensbachian).

Major facies: Ironstone was laid down in a shallow marine depression, underlain and overlain by claystone. Some cross-bedding. The lower part of the ore bed is "chamositic", the upper limonitic. Laterally the ironstone passes into thin sideritic marlstone.

Main minerals: Goethite (limonite), siderite, and "chamosite". The limonite ore is considered as secondary, derived by oxidation of the chamosite variety. Siderite and pyrite are diagenetic.

Chemical composition (%): Fe 25–30, Mn 0.6–0.8, SiO_2 18–20, Al_2O_3 13–15, CaO 5–7, P 0.6–0.7. The goethite ore is enriched in Fe and SiO_2 and impoverished in CaO when compared with the "chamosite"-siderite ore.

Ref.: J. Petránek. Bottke, 1969; Neumann-Redlin et al., 1977/1978.

118 – Keilberg ooidal ironstone

Keilberg, northeast of Regensburg, southeastern Germany. Ironstone is 1–2 m thick, ooidal, finely gravelly and consists mainly of hematite and goethite.

Age: Early Jurassic (Pliensbachian).

Major facies: Predominantly ferruginized, finely fragmented organic debris with dispersed ooids, laid down in a marine lagoonal environment.

Chemical composition (%): Fe 23–44, SiO_2 10–30, CaO 2–36.

Ref.: J. Petránek. Berg and Karrenberg, 1942.

119 – Ooidal ironstones

Other ooidal ironstones of Early Pliensbachian age occur at the eastern border of the Rhenish Massif (Egge Mts.), in the northern (Rottorf) and western foreland of the Harz Mts. (Markoldendorf). The deposits are small to medium-sized, mostly calcareous, and outcropping.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978.

120 – Ooidal and conglomeratic ironstone of Bodenwöhr

Near the border with the Bohemian Massif, 30 km northeast of Regensburg, southern Germany. Steep to overturned, 0.8 to 3.5 thick ore layers, mined in the last century.

Age: Early Jurassic (upper Pliensbachian).

Major facies: Laid down in a marine embayment in the Bohemian Massif.

Main minerals: Goethite, hematite, siderite, magnetite, and "chamosite".

Diagenetic processes: Replacement of ooids, calcareous matrix and fossils by magnetite, filling of voids by "chamosite" and siliceous hematite, and finally oxidation of ironstone.

Chemical composition (%): Fe 23–46, Mn 0.04–0.9, SiO_2 10–44, CaO 0.1–2.2, P 0.33–1.5 and S 0.01–0.05.

Ref.: J. Petránek. Berg and Karrenberg, 1942; Neumann-Redlin et al., 1977/1978.

Middle Jurassic

121 – Kahlenberg ooidal ironstone

Extensive deposit, situated in Upper Rhine graben north of Freiburg, southwestern Germany. Subhorizontal faulted strata. The main ore bed is 10–11.5 m thick. Mining ended in 1969.

Age: Middle Jurassic (late Aalenian)

Major facies: Calcareous marine ironstone with marly and argillaceous interbeds is transitional to limestone or claystone. Main minerals: Goethite and calcite, some hematite, "chamosite", siderite, quartz, clay minerals and phosphorite.

Diagenetic minerals: Mainly siderite and some calcite.

Chemical composition (%): Fe 17–23, Mn 0.15–0.23, SiO_2

11–18, Al_2O_3 3.4–5, CaO 20–30, MgO 0.8–1.6, P 0.25–0.35, S 0.04–0.08, Ti 0.09 and V 0.03.

Ref.: J. Petránek. Aldinger and Frank, 1942; sine, 1956; Neumann-Redlin et al., 1977/1978.

122 – Schönberg ooidal ironstone

Situated in Upper Rhine graben, south of Freiburg, southwestern Germany. Marine, calcareous goethite ironstone. Ore bed is 4–7 m thick. Mining ended in 1972. About 5 km southwest, the ore of the same stratigraphic horizon was mined until 1939 (Steinberg mine).

Age: Middle Jurassic (late Aalenian) – equivalent of the Kahlenberg deposit.

Chemical composition (%): Fe 19–23, Mn 0.12–0.15, SiO_2 14–20, Al_2O_3 5–6, CaO 16–24, MgO 1.5, P 0.24–0.34, S 0.03–0.06, Ti 0.27.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978.

123 – Aalen-Wasseralfingen ooidal ironstone

In Swabian Alb (Baden-Württemberg), east-northeast of Stuttgart, southern Germany. The ooidal ironstone, some kilometers long, is enclosed in a formation of sandy claystone and sandstone. There are three ore beds two of which are 1.4–2.4 m thick. Mining ended in 1948.

Age: Middle Jurassic (late Aalenian).

Major facies: Ironstones in very wide vicinity are marine, marginal to the Vindelician land and occur as individual lenses at different stratigraphic levels. Plant fossils in ironstone. Basinward transitions into sandstone, sandy shale, and marlstone or shale.

Main minerals are goethite, "chamosite" and siderite.

Chemical composition (%): Fe 29.3, Mn 0.39, SiO_2 27–32.6, Al_2O_3 5.2–7.1, CaO 3.1–5.8, P 0.28, S<0.1, Ti 0.23.

Ref.: J. Petránek. Aldinger and Frank, 1942; Neumann-Redlin et al., 1977/1978.

124 – Geislingen ooidal ironstone

In Swabian Alb (Baden-Württemberg), east-southeast of Stuttgart, southern Germany. Extent 15 km by 0.5–0.7 km, enclosed in sandy claystone and sandstone formation, subhorizontal. Several ore layers, the main ore seam is 1.8–2.7 m thick. Mining ended 1965.

Age: Middle Jurassic (late Aalenian).

Major facies: Marine, shallow-water sediment, cross-bedded, with very well sorted ooids.

Main minerals: Goethite, calcite, clay, chamosite, siderite, pyrite (interbeds). Diagenetic siderite and pyrite replace the earlier minerals.

Chemical composition (%): Fe 34.9, Mn 0.5, SiO_2 19.9, Al_2O_3 5.8–6.2, CaO 9, P 0.3, S 0.06, Ti 0.24, V 0.17.

Ref.: J. Petránek. Aldinger and Frank, 1942; sine, 1956; Neumann-Redlin et al., 1977/1978.

125 – Pegnitz ooidal ironstone

In Franconian Alb, northeast of Nürnberg. Ironstone 1.5–2.3 m thick is enclosed in subhorizontal strata. Extent is 4 x 1.5 km. Mining ended in 1967. The related deposits of Langenreuth and Zogenreuth exist close to Pegnitz.

Age: Middle Jurassic (late Aalenian).

Major facies: Marine ironstone is marginal to an extensive sand bar which is parallel with the coast. Ironstone is enclosed in sandstone. Limonite-cemented sandstone with dispersed introduced ooids is common.

Main minerals: Goethite and quartz, minor amounts of "chamosite", siderite and clay minerals.

Chemical composition (%): Fe 28.3, Mn 0.23, SiO_2 40.2, Al_2O_3 8.9, CaO 0.6, MgO 0.8, P 0.30, S 0.1, Ti 0.18.

Ref.: J. Petránek. Berg and Karrenberg, 1942; Neumann-Redlin et al., 1977/1978.

126 – Staffelstein ooidal ironstone

In Franconian Alb, north of Nürnberg. Marine ironstone is 0.4–0.9 m thick and enclosed in horizontal strata. Mining ended in 1937.

Age: Middle Jurassic (late Aalenian).

Main minerals: Goethite, siderite and "chamosite".

Chemical composition (%): Fe 35–45, Mn 0.41, SiO_2 20–25, Al_2O_3 5.7–7.2, CaO 1.5–2.5, P 0.28, Ti 0.46–0.77.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978.

127 – Vorra and Hohenstadt ooidal ironstone

In Franconian Alb, east of Nürnberg. The main ore seam is 0.5–2 m thick, locally 4 m, horizontally lying. Development similar to Pegnitz ironstone. (Another deposit occurs at Pfraunfeld near Weissenburg).

Age: Middle Jurassic (Aalenian).

Marine setting. Main mineral is goethite.

Chemical composition (%): Fe 24–34, Mn 0.2, SiO_2 38–46, Al_2O_3 4.86–6.8, CaO 0.7–1.4, P 0.2–0.36, S approx. 0.1, Ti 0.51, V 0.03.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978.

128 – Staffhorst ooidal ironstone

Northwestern Germany, 46 km south of Bremen. Very extensive deposit (14 x 2.5–7 km) at a depth of 700 to 1650 m. The ironstone is 2.5–8 m thick (average 3.3 m), underlain and overlain by claystone and occurs in a broad, faulted syncline. The same ore horizon occurs west-southwest of Staffhorst near Barenburg, Buchhorst, and Düste. Test mining abandoned in 1965.

Age: Middle Jurassic (late Aalenian).

Major facies: Laid down relatively far from the coast. Ironstone thins toward the submarine sills and becomes argillaceous-sideritic or chamositic with sporadic ooids.

Main minerals: "Chamosite" and siderite ooids in siderite matrix. Magnetite in the central part.

Chemical composition (%): Fe 38, Mn 0.5, SiO_2 7, Al_2O_3 6, CaO 5, MgO 3.4, P 0.8, S 0.4, Ti 0.13. Magnetite ore: Fe 38–44, SiO_2, Al_2O_3, CaO each 4–7; "chamosite" ore: Fe 32–38; siderite ore: Fe 30.

Ref.: J. Petránek. Gruss and Thienhaus, 1969a; Neumann-Redlin et al., 1977/1978.

129 – Friedeburg ooidal ironstone

Northwestern Germany, 20 km west of Wilhelmshaven. Situated above and at the side of a salt dome, at a depth of

1100–1800 m. Ironstone occurs within a faulted, shallow syncline and extends for more than 40 sq. km. There are two ironstone layers (hematite-goethite and "chamosite"-siderite), the main one is 8–16.7 m thick.

Age: Middle Jurassic (late Aalenian).

Major facies: Marine ooidal ironstone, containing ferruginous detrital material, is enclosed in claystones. The marginal facies is thin "chamosite"-siderite ore, rich in clay, without ferruginous detritus and is transitional into claystone.

Main minerals: The lower part of the main layer: siderite, "chamosite", goethite (Fe 30–40 %); the upper part: goethite, siderite, "chamosite" (Fe 40–50 %).

Chemical composition (%): Fe 37–43, Mn 0.4–0.55, SiO_2 6.6–8.4, Al_2O_3 5.6–6.9, CaO 3.1–5.4, MgO 2.6, P 0.8–1.5, S 0.3.

Ref.: J. Petránek. Thienhaus, 1969b; Neumann-Redlin et al. 1977/1978.

130 – Schaphusen ooidal ironstone

Northwestern Germany, east of Bremen. The marine ironstone occurs in a local basin, flanking a salt dome, at a depth of 1,600–1,900 m. Iron content of the magnetite-bearing "chamosite"-siderite ore is unusually high (up to 54 %).

Age: Middle Jurassic (late Aalenian).

Chemical composition (%): Fe 45–48, SiO_2 6.5–8, CaO 2–3, P 0.9.

Ref.: J. Petránek. Gruss and Thienhaus, 1969b.

131 – Ortland ooidal ironstone

North of Osnabrück, northwestern Germany. At a depth of about 600 to 1000 m, marine siderite-goethite ironstone up to 8 m thick, averaging (%) Fe 35.3, SiO_2 6.2, CaO 3.6, P 0.75.

Age: Middle Jurassic (Aalenian). The related Vestrup ooidal ironstone occurs 8 km northeast of Ortland.

Ref.: J. Petránek. Gruss and Thienhaus, 1969c; Neumann-Redlin et al., 1977/1978.

132 – Ooidal ironstones of northeastern Mecklenburg

Known from boreholes in northeastern Germany (near Greifswald).

Age: Middle Jurassic (Bathonian).

Major facies: Laid down in a marginal bay in a slightly reducing environment.

Main minerals: siderite, iron chlorite, limonite and calcite.

Chemical composition (%): Fe 24, Mn 0.2, SiO_2 19, Al_2O_3 10, CaO 8, MgO 2, P 0.7.

Ref.: J. Petránek. Bach et. al., 1977/1978.

133 – Gutmadingen and Blumberg ooidal ironstone

Swabian Alb, east of Freiburg(Baden-Württemberg), southern Germany. The ore seam is subhorizontal, 3.5–4 m thick. The mining ended 1942. The reserves of the unminable ore in the district are 500 to 1,500 million tons.

Age: Middle Jurassic (early Callovian).

Major facies: Marine ironstone is underlain by clay, marl and limestone and overlain by limestone.

Main minerals are goethite, "chamosite" and siderite. Goethite ooids contain 49.7 % Fe, the clay and marl matrix 8.14 % Fe. Siderite and pyrite replace the other minerals.

Chemical composition (%): Fe 22.5, Mn 0.15, SiO_2 22.15, Al_2O_3 8.8, CaO 11.15, P 0.38, S 0.48, Ti 0.24, V 0.08.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978; Sauer and Simon, 1975.

134 – Porta ooidal ironstone

Northwestern Germany, near Minden, west of Hannover. The ironstone outcrop is 20 km long with two major ore lenses; in a 5 km long zone the ore seam is 1.2–2.5 m thick. Inclined and faulted strata. Mining ended in 1962.

Age: Middle Jurassic (middle Callovian).

Major facies: Marine. The main ore seam, rich in fossils, is underlain by calcareous sandstone and overlain by clay. Ironstone lenses are on the flanks of a submarine swell and in basins.

Calcareous and argillaceous siderite with variable quantity of ooids. The basal part of the ironstone is sandy, the top is argillaceous siderite rich in pyrite, grading into the overlying clay.

Main minerals: Siderite, pyrite, calcite, quartz, clay minerals, phosphorite. Ooids are built by a complex clay mineral.

Extensive diagenetic processes resulted in sideritization, calcitization and pyritization.

Chemical composition (%): Fe 25.6, Mn 0.27, SiO_2 13.2, Al_2O_3 8.5, CaO 8.6, MgO 2.58, P 0.56, S 0.47.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978; Thienhaus, 1969c.

Late Jurassic

135 – Harzburg (Hansa) ooidal ironstone

Northern foreland of Harz Mts., north-central Germany. Two ironstone layers 5–30 m thick, steeply dipping and overturned. Main minerals are goethite and "chamosite". Mining ended in 1960.

Age: Late Jurassic (late Oxfordian).

Major facies: Shallow marine environment with predominantly limestone and marlstone deposition. Stratigraphic substratum of the ironstone is claystone, the roof claystone and limestone with sparse ooids at the base.

Chemical composition (%): Fe 23.7, SiO_2 9.5, CaO 19.6, P 0.24.

Ref.: J. Petránek. Dengler and Simon, 1969; Neumann-Redlin et al., 1977/1978.

136 – Weser Mts. (Nammen) ooidal ironstones

Northwestern Germany, southwest of Hannover. Three ironstone layers at various stratigraphic positions in an area 25 x 8 km. Inclined strata. Related to Gifhorn ironstones.

Age: Late Jurassic (late Oxfordian).

Major facies: Ironstones formed at the transition of estuarine into basinal limestone facies. Ironstones (partly cross-bedded) related to transgressive phases, were trapped in local basins, and enclosed in sandy marlstone and sandstone or in limestone.

Main minerals: Goethite, hematite, "chamosite", siderite.

Chemical composition highly variable.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978; Thienhaus, 1969d.

137 – Gifhorn ooidal ironstone

A 60 km long synsedimentary trough (500 km2), north of Harz Mts., west and north of Braunschweig in north-central Germany, with four ironstone layers at the average depth of 1,000–1,200 m. Mostly in shallow faulted synclines between the salt diapirs. Closely related to Weser Mts. ironstones. The lower ironstone is up to 18 m thick (southern part of the trough), the upper up to 8 m thick (northern part of the trough). Mined until late 1970s.

Age: Late Jurassic (late Oxfordian).

Major facies: Marine cross-bedded ironstones laid down in areas of synsedimentary subsidence. Ironstone sequence underlain and overlain by limestone and marlstone, laterally passes into sandy or calcareous facies. Relation to transgression.

Main minerals: Goethite with some "chamosite" (mostly secondarily oxidized) and siderite. Hematite ooids occur near the salt diapirs. Siderite, pyrite, and phosphate are diagenetic.

Chemical composition of the lower ironstone in Bleckenstedt area (southern end of the trough) (%): Fe 30–34, Mn 0.1–0.3, SiO_2 8–24, Al_2O_3 5–8, CaO 4–20, P 0.2–0.4, S 0.35, Ti 0.09.

Ref.: J. Petránek. Kolbe and Simon, 1969; Neumann-Redlin et al., 1977/1978.

138 – Western Prignitz ooidal ironstone

Marine ironstone known from boreholes southeast of Schwerin, northern Germany.

Age: Late Jurasic (Oxfordian).

Two ore layers 2–3 m thick (goethite, siderite, pyrite) in marly and sandy sequence; they contain 29–34 % Fe, 12–25 % SiO_2 and 6–9 % CaO.

Ref.: Bach et al., 1977/1978.

Early Cretaceous

139 – Salzgitter district – mixed ooidal and detrital ironstones

Ironstones occur south of Braunschweig in the northern foreland of Harz Mts., north-central Germany. Ironstones are of transgressive nature, inclined, preferentially laid down in areas of synsedimentary subsidence (partly of halokinetic nature). Economically very important deposits were mined in open pits and underground until the late 1970s; they were exploited for about 2,000 years.

Age: Early Cretaceous(Valanginian to Aptian).

Major facies: Marine ironstones deposited in submerged valleys offshore the Neocomian coast and in various depressions. The thickness of ore beds is from 5 to 30 m, but in synsedimentary tectonic depressions the ironstone thickness may exceed 100 m.

Upon nearby land, the Liassic and Dogger formations, rich in clay-ironstone concretions, were exposed to weathering and their ferruginous constituents oxidized, reworked and redeposited as detrital ore. Simultaneously ferruginous ooids formed. These processes continued througout entire Early Cretaceous which explains the extent of iron accumulation.

The ironstones occur on both sides of the Salzgitter ridge; they are primarily detrital in the south and become more and more ooidal northward.

The main component of the individual or mixed ore types is goethite with some "chamosite" and siderite; the matrix is quartz, clay minerals, goethite and carbonate.

Chemical composition (%): Fe 26–42, SiO_2 17–32, Al_2O_3 6–10, CaO 4–11, MgO 1–2, P 0.3–0.7, S 0.1–0.2, Mn 0.1–0.3, Ti 0.10–0.13, V 0.11.

Ref.: J. Petránek. Berg, Dahlgrün et al., 1942; Kolbe, 1970; Neumann-Redlin et al., 1977/1978.

140 – Kleiner Fallstein ooidal and detrital ironstones

Ironstones of the Salzgitter type occurring south-southeast of Salzgitter, in the northern foreland of Harz Mts., north-central Germany. Two ironstone layers averaging 10 and 6 m, laid down in narrow synsedimentary depressions.

Age: Early Cretaceous (late Hauterivian to Aptian).

Ref.: Bach et al., 1977/1978.

141 – Ooidal and detrital ironstones of North German Lowlands

Ironstones were detected by drilling in numerous places at depths excluding any economic use.

Ref.: Neumann-Redlin et al., 1977/1978.

Late Cretaceous

142 – Detrital ironstones of northwestern Germany

In the North German Lowlands significant deposits occur in Santonian of the Peine-Ilsede district; other deposits are Damme (Campanian), Bülten and Lengede (both Santonian).

The ironstones are derived from redeposition of Early Cretaceous oxidized ferruginous material and are lacking ooids in contrast to their Early Cretaceous predecessors.

Ref.: J. Petránek. Neumann-Redlin et al., 1977/1978.

Paleogene

143 – Kressenberg and Sonthofen ooidal ironstones

Near Traunstein and Sonthofen, southern Germany. In folded and faulted strata of the Helveticum zone of the Bavarian Alps. Several abandoned mines.

Age: Late Paleocene, and Early and Middle Eocene. In Illerdian (Late Paleocene) Schmalflöz beds, in the Cuisian (Early Eocene) Roterz beds, and in Lutetian (Middle Eocene) Schwarzerz beds.

Major facies: Epicontinetal shallow sea.

As many as 5 ironstones in the sequence, 1–3 m thick, in quartz sand and fossil remains. In some layers are also glauconitic peloids.
The weathered ooids are essentially goethite or goethite and berthierine.
The chemical composition of the Early and Middle Eocene ironstones (%): Fe 25.7–29.9, SiO_2 15.9–20.8, Al_2O_3 1.9–2.28, CaO 16.3–16.4, MgO 1.34–2.26, Mn 0.15–0.19, P 0.15–0.19.
Ref.: P. Simon. Ziegler, 1983.

Guinea

Silurian

144 – Ooidal ironstone

In the Bove Basin, or the West Guinea syncline, northwest Guinea. In folded strata. An uneconomic deposit.
Age: Early-Late Silurian (Wenlockian-Ludlowian). In mudstone of the Telimele Group.
Ref.: Romanko, 1975.

Early Devonian

145 – Ooidal ironstone

In the Bove Basin, or West Guinea syncline, northwest Guinea. In folded strata. Uneconomic deposits.
Age: Early Devonian: Lochkovian and Pragian (Gedinnian and Siegenian). In mudstone of the Fara Group.
Ref.: Romanko, 1975.

Hungary

Middle Jurassic

146 – Ooidal ironstone

Near Siklos, Baranya Province, about 33 km south of Pecs in southernmost Hungary. In faulted strata. An uneconomic deposit.
Age: Middle Jurassic (Callovian). In upper part of the Villany Formation, in a limestone sequence.
Major facies: Transgression of a shallow sea in a passive margin.
The ironstone is as much as 20 cm thick, and it is unaltered or moderately weathered.
Ref.: A. Torok. Greczy, 1986.

India

Late Permian

147 – Ooidal ironstone

In the Raniganj coal field in Burdwan District. Bengal Province, northeastern India. In folded strata. Abandoned mines.
Age: Late Permian. In the marine middle Ironstone Shale division of the Damuda Group (late Gondwana System).
The ooids are limonite and siderite.
The average chemical composition (%): Fe 43.9, SiO_2 18, Al_2O_3 6, Mn 1.8, P_2O_5 0.7.
Ref.: Krishnan, 1955.

Early Triassic

148 – Ooidal ironstone

In the Zanskar area, north of Padum, Kashmir.
Age: Early Triassic (Scythian). Ironstone lies near the top of limestone and is overlain by Anisian marly limestone.
Ref.: Garzanti, 1993.

Late Triassic

149 – Ooidal ironstones

In the Zanskar area, about 20–25 km north of Padum, Kashmir. In the lower part of the Quartzite Series (about 200 m) along about 100 km east-west. In meta-sedimentary rocks. An uneconomic deposit.
Age: Late Triassic (early Norian). Over the Quartzite Series is the Rhaetian (lower) Kioto limestone and below it is the Carnian Zozar Formation. The lower part of the Quartzite Series, as much as 100 m thick, contains two ironstones as much as 20 m thick.
Major facies: Storm-dominated shallow marine environment.
Ooids, as much as 50 per cent of the framework, are chamosite and goethite in various proportions.
Diagenetic effect: Probably berthierine was changed to chamosite and goethite.
Ref.: Garzanti et al., 1989.

Middle Jurassic

150 – Ferruginous Oolite Formation

In the Zanskar area 20–25 km north of Padum, Kashmir, and extends about 100 km east-west. In meta-sedimentary rocks. An uneconomic deposit.
Age: Late Middle Jurassic (Callovian). Ferruginous Oolite Formation overlies the Liassic (upper) Kioto Limestone and underlies Oxfordian Spiti Shale. The formation is 15 to 30 m thick, built of mudstone and sandstone, with an ironstone up to several meters thick at the base and at the top of the formation.
Major facies: In storm-dominated shallow sea.
Ooids consist of abundant chamosite and goethite, locally oxidized to "limonite". Phosphate clasts are sporadic.
Diagenetic effect: Probably berthierine was changed to chamosite and goethite.
Ref.: Garzanti et al., 1989.

Iraq

Early Jurassic

151 – Hussainiya ooidal ironstone

In Wadi Hussainiya 45 km northeast of Rutbah in western Iraq. In horizontal strata. Possibly has a future potential.

Age: Early Jurassic. The 19–24 m thick Hussainiya Member overlies unconformably the uppermost Triassic (Rhaetian) Zor Horan Formation of carbonate and black claystone, and underlies Ubaid Dolomite (late Early Jurassic).

Major facies: A shallow sea? or lake? during regression in a cratonic interior.

The ironstone averages 2.4 m in thickness. It lies on claystone and below sandstone.

The ooids and pisoids consist of goethite and minor hematite. Matrix is quartz sand and clay.

The average chemical composition of the ore (%): Fe 23.65, SiO_2 31.9, Al_2O_3 11.5–38.4, CaO 1–3.2, MgO 0.2–1.9, Ti 0.24–1.38, P 0.01–0.16.

Ref.: V. Skoček. Skoček, et al., 1971.

Ireland

Early Carboniferous

152 – Hook Head ooidal ironstone

In the Hook Peninsula near Waterford, Co. Wexford in southeasternmost Ireland. In folded and faulted strata. An uneconomic deposit.

Age: Early Carboniferous (Tournaisian). In the basal part of the Hook Formation with the mudstone and thin limestone.

Major facies: Shallow shelf.

The ironstone 10 cm thick is 2.1 m above the base of the Hook Head Formation. The ooids are hematitic.

Ref.: E. Cotter. Sleeman et al., 1974.

Israel

Early Cretaceous

153 – Ooidal ironstones

In the coastal plain northeast of Gaza. An uneconomic deposit.

Age: Early Cretaceous (Berriasian).

Major facies: A shallow sea.The ooids are composed of goethite.

Ref.: V. Rohrlich. Rohrlich et al., 1980.

154 – Ooidal ironstones

In southern coastal plain, in the central part of Israel, and in the north Israel. An uneconomic deposit.

Age: Early Cretaceous (early Aptian).

Major facies: A shallow sea. The ooids are composed of goethite.

Ref.: V. Rohrlich. Rohrlich et al., 1980.

155 – Ramim and other ooidal ironstones

In Mt. Ramim north of the Sea of Galilee in northern Israel and in southern coastal plain. In folded and faulted strata. Ramim ironstone has a future potential.

Age: Early Cretaceous (late Aptian). Ramim ironstone is in the Hidra Formation.

Major facies: A marine shoreline or offshore shelf during a regional transgression.

The Ramim ironstone is associated with carbonate and black shale. The ironstone is as much as 1.8 m thick. The ooids are goethite with matrix of quartz and clay and the cement of carbonate.

The chemical composition of the Ramim ore (%): Fe 26–30, SiO_2 10–12, Al_2O_3 7.4, CaO 17.1, MgO 1.2, P 0.44.

Ref.: V. Rohrlich. Rohrlich et al., 1980; Zitzmann, 1977/1978a.

156 – Maktesh and other ooidal ironstones

In Hamaktesh Hagol 45 km south of Beersheba, and in central Israel. In folded strata. Uneconomic deposits.

Age: Early Cretaceous (Albian). Maktesh Gadol ironstone is in the middle of the Hatira Formation; glauconitic beds are in the upper part of the formation. The ironstones in the central Israel are in the Tamun Formation.

Major facies: A marine shoreline during regional transgression.

The Maktesh Gadol ironstone is associated with sandstone and carbonate. It is as much as 1.6 m thick. The ooids are composed of goethite with quartz nuclei.

The chemical composition of the Hatira ironstone (%): Fe_2O_3 36.6, SiO_2 13.9, Al_2O_3 7.7, CaO 16.7, MgO 2.4, P_2O_5 1.4.

Ref.: V. Rohrlich. Rohrlich et al., 1980; Zitzmann, 1977/1978a.

Italy

Silurian

157 – Val Canale ooidal ironstone

In Malborghetto Ugovizzo near Tolmezzo in Udine Province in the Carnian Alps, in northeasternmost Italy. In thrusted and faulted strata. An abandoned mine and uneconomic outcrops.

Age: Early to Late Silurian (Late Llandoverian to Early Ludlowian). In the Mount Cocco and Aulacopleura Limestone formations in the Orthoceras Limestone group.

Major facies: A shallow marine setting during a regional transgression in a rifted cratonic margin.

The 2–3 layers of ironstones as much as 3.5 m thick are enclosed in limestone. The lowest ironstone is rich in magnetite in the lower part and rich in siderite in the upper part.

The ooids and a few pisoids consist of hematite, siderite, and magnetite, with minor goethite, chamosite, sulfide, and apatite. Pyrolusite, psilomelane, and braunite are also present.

Diagenetic effect: Ooids were changed to hematite, magnetite and sulfide.

The average chemical composition: Fe_2O_3 16–42 %, MnO 2–39 %.

Ref. G. B. Vai. Zitzmann, 1977/1978b.

Kazakhstan

Late Devonian

158 – Ooidal ironstone

In the Uspensky-Spassky district in the Ulutan Mountain and Dzhezdy River basin, central Kazakhstan. In folded strata. An uneconomic deposit.

Age: Late Devonian (upper Famennian).

Ironstone is at the top of the sandy limestone, overlain by Carboniferous marlstone and argillite as much as 250 m thick.

Major facies: A shallow sea.

The ironstone is a thin bed of greenish gray and black. The ooids are composed of hematite, magnetite, ferric chamosite, and siderite. When oxidized the ooids are largely goethite or martite.

Ref.: Maksimov, 1960.

Late Cretaceous

159 – Ayat ooidal ironstone

Lies about 20 km north of Tobol and 80 km southwest of Kustanay in Turgay district in north-central Kazakhstan. In horizontal strata in outcrop and mine. Has future potential.

Age: Late Cretaceous (Turonian to Santonian) in a sandstone and mudstone.

Major facies: A shallow inland sea during regional transgression in a cratonic interior.

The ironstone lies transitionally above a Cenomanian glauconitic quartz arenite and claystone and below latest Cretaceous sandstone and mudstone. The ironstone is 2 to 9 m thick, with thin, lenticular glauconite interbeds. The ironstone is both fresh and altered.

The ooids and pisoids vary. In the lower part of the ironstone the size is large (1 to 4 mm), in the upper part small (0.01 to 1 mm). Many of the ooids and pisoids are crushed.

The ooids and pisoids consist mainly of goethite and minor berthierine and siderite.

Average chemical composition (%): Fe 37.1, SiO_2 16, Al_2O_3 7.3–8.6, P 0.37–0.4.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

Paleogene

160 – Lisakovsk, Shiyelya, Kirov, and Dzhalsky Klysch ooidal ironstones

In an area 100 to 120 km southeast and southwest of Kustanay in the Turgay basin, north central Kazakhstan. In horizontal strata in outcrops. A future potential.

Age: Paleogene (middle Oligocene).

In sandstone and mudstone overlying late Eocene and early Oligocene marine Chegan beds.

Major facies: Probably an alluvial deposit.Cross-bedded ironstones are from a few meters to a few tens of meters thick.

The ooids are both fresh and altered. They consist of goethite, berthierine, and siderite, and minor pyrite and pyrrhotite, with a matrix of berthierine, siderite, calcite, and goethite.

Average Lisakovsk chemical composition (%): Fe 42.6, SiO_2 19.3, Al_2O_3 5.2, CaO 0.35, MgO 0.32, P 0.55.

Ref.: D. I. Pavlov. Zitzmann 1977/1978e.

161 – Kashkarata (Taldy) ooidal ironstone

Near Chelkhar and Emba in the Chelkhar-Kurgautuz trough, western Kazakhstan. In horizontal strata in outcrop and boreholes. An uneconomic deposit.

Age: Paleogene (middle or late Oligocene).

Major facies: Probably in a nearshore marine setting during local prograding in a cratonic interior. The ironstone lies in a transition zone between the sandy and clayey sediments and is up to 20 m thick.

The ooids consist of goethite and berthierine, with siderite, berthierine, and goethite cement.

Average chemical composition (%): Fe 37.7, SiO_2 27.4, Al_2O_3 5.4, CaO 2.3, MgO 1.2, P 0.6, Ti 0.33.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

162 – Kutan Bulak, Taldy-Espe, Kok Bulak, and Kara Sandyk ooidal ironstones

In the North Priaral area of the Priaral region near Aralsk and Saksaulskiy in west-central Kazakhstan. In horizontal strata in outcrops. Has future potential.

Age: Paleogene (middle and late Oligocene). In sandstone and mudstone overlying late Eocene-early Oligocene Chegan Beds.

Major facies: Nearshore marine to alluvial settings during regional transgression in a cratonic interior.

The ironstones are 1 to 20 m thick, in both fresh and altered condition, and they are cross-bedded.

The ooids and pisoids are goethite, berthierine, and siderite, with minor hematite, calcite, ankerite, sulfide, and apatite.

Chemical composition (%): Fe_2O_3 18.9–65.5, MnO 0.1–0.2, SiO_2 7.3–46.4, Al_2O_3 7.5–9.0, P_2O_5 0.45–2.04.

Ref.: D. I. Pavlov, E. V. Golubovskaya and A. V. Lipayeva. Zitzmann, 1977/1978e.

Lebanon

Early Cretaceous

163 – Ooidal ironstones

Near Hammana in central Lebanon, and near Kanate in northern Lebanon. An uneconomic deposit.

Age: Early Cretaceous: Lower Aptian in the Kanate ironstone; late Aptian in the Hammana ironstone.

Major facies: A shallow sea. The ironstones are in Aptian sandstone and overlain by Albian limestone.

The ooids are of goethite.

Ref.: Rohrlich et al., 1980; Zitzmann, 1977/1978c.

Libya

Early Ordovician

164 – Ooidal ironstone

In northern Tripolitania, northwest Libya. In a borehole. An uneconomic deposit.

Age: Early Ordovician.

Major facies: A shallow shelf.

The ooids are mainly chamosite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Middle Ordovician

165 – Ooidal ironstone

In northern Tripolitania, northwest Libya. In a borehole. An uneconomic deposit.

Age: Middle Ordovician.

Major facies: A shallow shelf.

The ironstone is enclosed in siltstone and sandstone. The ooids consist of chamosite, siderite, sericite, goethite, quartz, and apatite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Late Ordovician

166 – Ooidal ironstone

In the Jebel Fezzan, central Libya. In a borehole. An uneconomic deposit.

Age: Late Ordovician (Caradocian). In the Melez-Chograne Formation.

Major facies: A shallow shelf.

The ironstone is enclosed in coarse feldspathic sandstone.The ooids include chamosite, goethite, quartz, apatite, and siderite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Early Silurian

167 – Ooidal ironstones

In the western part of the Murzuq Basin, in west-central Libya. In a borehole. An uneconomic deposit.

Age: Early Silurian (Llandoverian).

Major facies: A shallow shelf.The ooids are mainly chamosite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Late Silurian

168 – Ooidal ironstones

In the eastern and northern Tripolitania, northwestern Libya. In boreholes. An uneconomic deposit.

Age: Late Silurian (Ludlowian).

Major facies: A shallow shelf.Ironstones are enclosed by sandstone and mudstone. The ooids include chamosite, hematite, goethite, and quartz.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Early Devonian

169 – Ooidal ironstones

In southern and eastern Tripolitania, northwestern Libya. In boreholes. An uneconomic deposit.

Age: Early Devonian (Emsian).

Major facies: A shallow shelf.

The ironstones are enclosed in coarse sandstone.

The ooids consist of chamosite, hematite, goethite, and quartz.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Middle Devonian

170 – Ooidal ironstone

In the Jebel Fezzan area, central Libya. In a borehole. An uneconomic deposit.

Age: Middle Devonian. Base of the Givetian in the Aouinet-Ouenine II Formation.

Major facies: A shallow shelf.

The ironstone is enclosed in sandstone.

The ooids are chamosite, goethite, and quartz.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

Late Devonian

171 – Ooidal ironstones

In the northern Tripolitania and in Jebel Fezzan, northwest and central Libya. In boreholes. An uneconomic deposit.

Age: Late Devonian – Frasnian (Aouinet-Ouenine III in northern Tripolitania), and Frasnian-Famennian (Aouinet-Ouenine IV in Jebel Fezzan).

Major facies: A shallow shelf.The ironstones are enclosed in sandstone and mudstone or by calcareous mudstone. The ooids may contain goethite, chamosite, siderite, calcite, quartz, apatite and magnetite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

172 – Wadi Shatti ooidal ironstone

In an area about 100 km long from 10 km west of Gotta to 40 km east of Brak, in the northeast margin of the Murzuq Basin, central Libya. In horizontal strata. Has future potential.

Age: Late Devonian (Famennian to Strunian). In four succeeding ironstones within the Frasnian to Tournaisian 150 m Shatti Formation.

Major facies: A shallow shelf to deltaic setting during regional transgression in a cratonic interior.

The four ironstones are each at the top of a coarsening upward sequence of mudstone to sandstone. The thicknesses are from a few cm to more than 5 m. Some are cross-bedded and burrowed. Peloids of collophane and kaolinite are common.

The ooids consist of goethite, hematite, chamosite, and magnetite, with minor quartz, apatite, and siderite.

Diagenetic effect: Goethite, hematite, siderite, chlorite, and pyrite were variously made from chamosite and magnetite.

The main chemical composition (%): Fe 47.38, SiO_2 36.43, Al_2O_3 3.8, P_2O_5 1.07.

Ref.: F. B. Van Houten. Guerrak, 1991; Turk et al., 1980; Van Houten and Karasek, 1981.

Early Carboniferous

173 – Ooidal ironstone

In the Dor el Goussa area in the northeast Murzuq basin in central Libya. In a borehole. An uneconomic deposit.

Age: Early Carboniferous (late Tournaisian). In the lower Mrar Formation.

Major facies: A shallow sea.

The ironstone is enclosed in mudstone, feldspathic sandstone, and microconglomerate.

The ooids are mostly chamosite and goethite.

Ref.: Chauvel and Massa, 1981; Guerrak, 1991.

174 – Ooidal ironstone

In the northeastern part of the Kufrah Basin in southeastern Libya. In a borehole, in folded strata. An uneconomic deposit.

Age: Early Carboniferous. In the lower part of the Dalma Formation.

Major facies: A shallow sea deposit overlain by nonmarine sandstone. The ferruginous ooidal ironstone occurs locally in mudstone.

Ref.: Bellini et al., 1991.

Early Cretaceous

175 – Nalut ooidal ironstone

In the Jebel Nafusah in northwest Tripolitania, northwest Libya. In horizontal strata. An uneconomic deposit.

Age: Early Cretaceous (Aptian-Albian). In the Chicla Formation of sandstone, mudstone, and marlstone.

Major facies: A shallow sea.

Ref.: F. B. Van Houten.

Luxembourg

Jurassic

176 – Esch and Differdange ooidal ironstones

In the Esch-Ottange and Differdange-Longwy basins in southwestern Luxembourg. In nearly horizontal strata. Almost all abandoned mines.

Age: Early-Middle Jurassic (Toarcien and Aalenian).

Major facies: A shallow sea with sub-tidal currents and waves.

The muddy and sandy ironstones are siliceous in the lower part and calcareous in the upper part, and a coquina bed at the top. The Esch ironstones reach a maximum of 55 m and the Differdange ironstones a maximum of 25 m in thickness.

As many as 13 coarsening-upward sequences are each 2 to 5 m thick, and some are cross-bedded and richer in ooids in the upper part.

The ooids consist of goethite, berthierine, and siderite, with matrix of quartz sand and silt and bioclasts.

Diagenetic effect: Berthierine was changed to goethite and siderite.

Average chemical composition of the siliceous Esch ironstone (%): Fe less than 35, SiO_2 12–15, CaO 7.5–12.

Ref.: A. Siehl and T. Teyssen. Neumann-Redlin and Zitzmann, 1977/1978b; Teyssen, 1989.

Macedonia

Devonian

177 – Taymishte ooidal ironstone

In western Macedonia, 4–5 km west of Taymishte village, 30 km northwest of Kichevo and 68 km southwest of Skoplje. In metamorphosed mixed siliciclastic-carbonate strata, with minor pyroclastic rocks. Currently exploited deposit.

Age: Early-Middle Devonian.

Major facies: An offshore marine shelf in a regional transgression. Ironstones are within the metamorphic sandstone, and phyllite lies above them; they are at the top of coarsening upward sequences in a conformable or transitional contact. Single thickness is less than a few meters; composite thickness is a maximum of 20–60 m.

Ooids are unweathered. Major ooids are composed of chamosite and siderite; minor ooids consist of apatite and pyrite. Matrix includes pyrite, apatite, stilpnomelane, magnetite, minnesotaite, quartz, Fe^{3+} chamosite, and organic matter.

Diagenetic effect: Berthierine was changed to chamosite early, siderite was late, and magnetite was late or metamorphic.

Average chemical composition (%): FeO 35–49, SiO_2 6–28, Al_2O_3 5–13. Composition in ppm: Pb 7–30, Zn 30–100, Cu 50–100, V 50–200.

Ref.: J. Obradović. Kleut, 1969.

Cretaceous

178 – Rzhanovo ooidal ironstone

A few km from the southern Macedonia border.In a siliciclastic sequence. An uneconomic but future potential deposit.

Age: Base of Late Cretaceous. Ironstone lies above serpentinite and Paleozoic schists and below Late Cretaceous strata.

Major facies: A marine shoreline during transgression. Partly redeposited lateritic material.

The ironstone is as much as 10 to 30 m thick. It contains pisoids as well as ooids.

Ooids are variously composed of hematite, goethite, maghemite, magnetite, and pyrite. Matrix is mostly quartz and clay minerals.

Average chemical composition (%): Fe 34.5, SiO_2 14–18, Cr 0.68–2.74, Ni 1.13, Co 0.085.

Ref.: J. Obradović. Janković, 1977/1978.

179 – Titov Veles ooidal ironstone
In an area 45 km southeast of Skoplje, eastern Macedonia. Chemical composition (%): Fe 40–50, SiO_2 10, Cr_2O_3 2–3.
Ref.: J. Obradović.

Malaysia

Ordovician

180 – ? Ooidal ironstone
In the northwestern part of Malaysia.
Age: Ordovician.
Ref.: F. B. Van Houten.

Miocene

181 – Terengganu ooidal ironstone
Under the South China Sea in subsurface on the Tenggol Arch, about 150 km east of the Malayan coast and Kuala Dungun. An uneconomic deposit.
Age: Late Early Miocene. Several beds of ironstones in 30–50 m thick Terengganu Shale of the Pulai Formation. Early Miocene Pulai Sandstone lies below the Terengganu Shale and the Tapis coarse-grained sandstone of late Early Miocene lies above it.
Major facies: In a restricted epicratonic sea during a sea-level highstand.
Ironstone bed as much as 45 cm thick is in the lowest 6 m of the Shale and is associated with coarse-grained sandstone. Other ironstones higher in the Shale are less than 1 cm thick. Both the ironstones and sandstone have sharp erosive bases. Phosphatic nodules are rare in the Shale.
Unweathered ooids consist of berthierine, goethite, and phosphate. Matrix mud is composed of berthierine, kaolinite, and illite.
Diagenetic effect: Berthierine ooids were partly replaced by kaolinite, goethite, and siderite.
Ref.: Madon, 1992.

Malgash Republic (Madagascar)

Middle Jurassic

182 – Mandabe ooidal ironstone
Near Mandabe in the west-central Madagascar. In gently folded strata. An uneconomic deposit.
Age: Middle Jurassic (Bajocian or Bathonian).
Major facies: A shallow shelf.
The ironstone less than a meter thick is enclosed in limestone.
The ooids consist of goethite.
Ref.: F. B. Van Houten.

Mali

Middle Devonian

183 – Ooidal ironstone
In the northeastern Taoudeni Basin in the northernmost Mali. In folded strata. An uneconomic deposit.
Age: Middle Devonian (Givetian).
Ref.: Hollard, 1967.

Paleogene

184 – Ooidal ironstone
In the Iullemmeden Basin near Gao along the Niger River, southeast Mali. In horizontal strata. An uneconomic deposit.
Age: Paleogene (late Eocene). In the Continental Terminal.
Major facies: In a lacustrine environment in a cratonic interior.
The ooids are goethite.
Ref.: Lang et al., 1990.

Mauritania

Early Silurian

185 – Ooidal ironstones
In the Mauritanian Adrar area south of Atar in the southwestern part of the Taoudeni Basin, west-central Mauritania. In folded strata. Uneconomic deposits.
Age: Early Silurian (Wenlockian?). In the middle sequence of the Oued Chig Group which lies on the Late Ordovician Abteilli Group.
Major facies: A shallow sea.The ironstones are in the upper sandy and silty part of the middle sequence which is about 42 m thick. They are associated with phosphatic nodules.
Ref.: Deynoux et al., 1985.

Early Devonian

186 – Ooidal ironstone
In the Mauritanian Adrar in the southwestern part of the Taoudeni Basin, west-central Mauritania.
Age: Early Devonian.
Ref.: Le Page, 1986.

Morocco

Middle Cambrian

187 – Tamjert ooidal ironstone
In the vicinity of Siksaoun in the central High Atlas, southern Morocco. In folded strata. An uneconomic deposit.
Age: Middle Cambrian. In lower Acadian shale.
Major facies: A marine offshore shelf.
Hematitic ooidal ironstone is 20 m thick.
Ref.: Destombes et al., 1985.

Early Ordovician

188 – Ooidal ironstone

In the Anti-Atlas in southern Morocco. In folded strata. An uneconomic deposit.

Age: Early Ordovician (Tremadocian). In the Lower Fezouata Shale, with chloritic ooids and glauconitic peloids.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

189 – Ooidal ironstone

In the valley of Oued Nefifikh east of Mohammedia in the coastal Meseta, western Morocco. In folded and faulted strata. An uneconomic deposit.

Age: Early Ordovician (early Arenigian). At the base of the Chabet Oukaref Formation that lies directly above Middle Cambrian (Acadian) El Hank Quartzite.

Major facies: A shallow sea.The ooids are ferruginous.

Ref.: Pique, 1979.

190 – Ooidal ironstone

In the Anti-Atlas in southern Morocco. In folded strata. An uneconomic deposit.

Age: Early Ordovician (Arenigian). On the unconformity below the Upper Fezouata Shale.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

Middle Ordovician

191 – Tachilla, Ouarzemine and Tazigzaout n'Achich ooidal ironstones

In Jbel Tachilla-Ouarzemine and Maider areas of Anti-Atlas in southern Morocco. In folded strata. Uneconomic deposits.

Age: Middle Ordovician (Llanvirnian). In the Tachilla Shale.

Major facies: A marine offshore shelf.

The Tachilla Shale contains 6 ironstones 0.5 to 20 m thick.

Average chemical composition (%): Fe 35–45, SiO_2 12–18, Al_2O_3 7–12, P_2O_5 0.5.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

192 – Tourza, Taklimt, Siguenite, and Mellal ooidal ironstones

In the Maider and Tafilalt areas in Anti-Atlas in southern Morocco. In folded strata. Possibly future potential.

Age: Middle Ordovician (late Llanvirnian or early Llandeilian). In the lower 1st Bani Sandstone Group.

Major facies: A marine shelf.

The Tourza ooids contain chamosite, siderite, magnetite, maghemite, hematite, goethite, stilpnomelane, and apatite.

Tourza chemical composition (%): Fe 52, SiO_2 8, P_2O_5 2.36.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

193 – Ait-Amar Ooidal ironstone

25 km northwest of Oued Zem in the Massif, western Morocco. In folded strata. In outcrops and mines. Possibly future potential.

Age: Middle Ordovician (Llandeilian).

Major facies: A marine offshore shelf.

The ironstone as much as 17 m thick is enclosed in shale.

The ooids contain chamosite, hematite, siderite, magnetite, pyrite, stilpnomelane, and apatite.

The chemical composition (%): Fe 43–48, SiO_2 11–17, Al_2O_3 8, P_2O_5 1.59.

Ref.: Destombes, 1977/1978; Guerrak, 1991.

194 – Ouled Said ooidal ironstone

Near Settat to the south of Casablanca in the coastal Meseta, western Morocco. In folded strata. An uneconomic deposit.

Age: Middle Ordovician (Llandeilian).

Major facies: A marine shallow shelf.

The ironstone 2 to 5 m thick is enclosed in sandstone.

The ooids contain hematite, chamosite, and siderite.

Average chemical composition (%): Fe 40.25, SiO_2 24.5, P_2O_5 1.8.

Ref.: Destombes, 1977/1978.

195 – Ooidal ironstone

At Jebel Zerouk in the eastern High Atlas in southern Morocco. In folded strata. An uneconomic deposit.

Age: Middle Ordovician (Llandeilian). In the base of the 1st Bani Group.

Ref.: Destombes et al., 1985.

196 – Zerouk and Tissoufi ooidal ironstones

In jbels Zerouk and Tissoufi near Ambej in the region of Tamlelt west of Figuig in the eastern High Atlas in the easternmost Morocco. In folded strata. Uneconomic deposits.

Age: Middle Ordovician (Llandeilian). In the base of the 1st Bani Group.

Major facies: A marine nearshore setting during regression.

The ironstones 5 to 7 m thick lie in sandy shale directly below the 1st Bani Sandstone.

The ooids contain goethite, hematite, and chamosite.

The chemical composition of three Tissoufi ironstones (%): Fe 38.4–41.8, SiO_2 24.1–34.2, Al_2O_3 1.2–2, MnO 0.6–3.8, P_2O_5 0.7–1.3.

Ref.: Destombes et al., 1985; Sattran and Petránek, 1980.

197 – Bou-Kerzia and Oumjerane ooidal ironstones

Near Maider in the Anti-Atlas, southern Morocco. In folded strata. Possibly future potential.

Age: Middle Ordovician (Llandeilian). In the 1st Bani Sandstone Group.

Major facies: A shallow marine shelf. The ironstones about 5 m thick are enclosed in sandstone and mudstone.

The Bou-Kerzia ooids contain goethite, magnetite, chamosite, and apatite.

The average chemical composition (%): Fe 41–44.5, SiO_2 12.5–13.2, Al_2O_3 10.34, P_2O_5 2.24.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

198 – Khaloua and Satour ooidal ironstones

About 50 km east of Rabat and northwest of the Central Hercynian Massif, northwestern Morocco. In folded strata. Possibly future potential.

Age: Middle Ordovician – Llandeilian (or Caradocian?).

Major facies: A nearshore shelf.

The ironstones 3 to 5 m thick are enclosed in sandstone. The ooids include goethite, chamosite, and siderite.

Average chemical composition (%): Fe 47–49, SiO_2 13–15, P_2O_5 0.6–0.7.

Ref.: Destombes, 1977/1978; Young, 1992.

199 – Feddan-Taba and Ain-Kerma ooidal ironstones

In the Oued Nefifikh in the Coastal Meseta in western Morocco. In folded strata. Uneconomic deposits.

Age: Middle and Late Ordovician (Llandeilian-Caradocian).

Ref.: Destombes, 1977/1978.

Late Ordovician

200 – Ed-Delaa ooidal ironstones

In the southwest of the Zaer granite in the Massif, western Morocco. In folded strata. An uneconomic deposit.

Age: Late? Ordovician.

Ref.: Destombes, 1977/1978.

201 – Ain-Ait-Ali ooidal ironstone

In the east of Mohammedia in the Coastal Meseta, western Morocco. In folded strata. An uneconomic deposit.

Age: Late Ordovician (Caradocian).

The ironstone is 1.8 to 2.1 m thick.

The chemical composition (%): Fe 50.6, Al_2O_3 3.85, P_2O_5 0.75.

Ref.: Destombes, 1977/1978.

202 – Ed-Debaa and Skoura ooidal ironstones

In the region of Skhours in the Rehamna south of the Ouled Said, western Morocco. In folded strata. Uneconomic deposits.

Age: Late Ordovician (Caradocian).

Ref.: Destombes, 1977/1978.

203 – Zegmoua and other ooidal ironstones

In the vicinity of Agadir-Tissint in the western Anti-Atlas in southern Morocco. In folded strata. Uneconomic deposits.

Age: Late Ordovician (middle Caradocian). In the Lower Ktaoua Formation.

Major facies: A shallow marine shelf.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

204 – Ooidal ironstones

In western Anti-Atlas in southern Morocco. In folded strata. Uneconomic deposits.

Age: Late Ordovician (Ashgillian).On the contact between the Rouid-Aissa and the Upper Ktaoua formations, and in the Agadir-Tissint Argillite.

Ref.: N. Hamoumi. Destombes, 1977/1978; Destombes et al., 1985; Guerrak, 1991.

Early Silurian

205 – Rhabt-el-Hejar ooidal ironstone

In the eastern Tafilalt in the easternmost Anti-Atlas, southern Morocco. In folded strata. An uneconomic deposit.

Age: Early Silurian (Llandoverian).

Major facies: A marine setting.

The ooids are mainly hematite.

Ref.: Destombes, 1977/1978; Destombes et al., 1985.

Early Devonian

206 – Rich-m'Bidia ooidal ironstones

In central Anti-Atlas south of Tagounite and near Ktaoua, southern Morocco. In folded strata. Uneconomic deposits.

Age: Early Devonian (early Lochkovian).

Major facies: A shalow sea.

In 3 or 4 layers. An ironstone is 0.2 to 0.8 m thick. Its ooids contain mainly hematite.

Chemical composition (%): Fe 34, SiO_2 12, Al_2O_3 3.5, P 0.7.

Ref.: Destombes, 1977/1978.

207 – Kenatar-Lamouna ooidal ironstone

Near Ceuta in the northern Rif in northernmost Morocco. In folded strata. An uneconomic deposit.

Age: Early Devonian (Lochkovian).

Major facies: A marine offshore shelf.

An ironstone less than 1 m thick is enclosed in shale.

The ooids contain hematite and chamosite.

Ref.: Destombes, 1977/1978.

208 – Ooidal ironstone

In the central part of northern Tindouf Basin, southernmost Morocco. In folded strata. An uneconomic deposit.

Age: Early Devonian (Pragian).

Ref.: D. P. Bhattacharyya.

209 – Bir Aidiate, Tighirt, and Khaneg Lejouad ooidal ironstones

In the area of Zemmoura on the eastern edge of the Bassin du Rio in the western Sahara of southwest Morocco. In folded strata. Uneconomic deposits.

Age: Early Devonian (Pragian).

Major facies: A shallow marine shelf.

The ironstones 0.7 to 2 m thick are enclosed in mudstone and limestone. The ooids include chamosite, goethite, hematite, and quartz or calcite.

The Bir Aidiate chemical composition (%): Fe 36.3, SiO_2 20, P_2O_5 2.7.

Ref.: Guerrak, 1991.

Early Carboniferous

210 – Ooidal ironstone

In the central part of northern Tindouf Basin south of Assa, southernmost Morocco. In folded strata. An uneconomic deposit.

Age: Early Carboniferous (Visean).

Ref.: D. P. Bhattacharyya.

Nepal

Late Devonian

211 – Ooidal ironstone

In Dolpo and Thakkhola districts, central Nepal. In folded strata. An uneconomic deposit.

Age: Late Devonian (Frasnian). Ooidal ironstone about 2 m thick separates an early Frasnian calcarenite from overlying later Frasnian shale.

Ref.: Garzanti, 1993.

Late Triassic

212 – Ooidal ironstones

In Dolpo and Thakkhola districts, central Nepal. In folded strata. An uneconomic deposit.

Age: Late Triassic (early Norian). Several horizons of ooidal ironstones lie above the Norian sandstone and below the later Norian sandstone.

Ref.: Garzanti, 1993.

Middle Jurassic

213 – Ferruginous Oolite Formation

In the Thakkhola district, central Nepal. Also to the west in the border of northern India and to the northeast in the area of southern Tibet. In folded strata. An uneconomic deposit.

Age: Middle Jurassic (Callovian). At the top of the Bathonian Bagung Formation and below the Oxfordian Nupra Shale.

Major facies: The ooidal ironstone represents a rapid rise in sea and drowning of the shelf.

Ref.: M. B. Hj. Madon. Jansa, 1991.

Niger

Paleogene

214 – Malbaza ooidal ironstone

Near Malbaza and Tahoua in south-west Niger. In horizontal strata. An uneconomic deposit.

Age: Paleogene (middle Eocene). In the Ader Douchti Group.

Major facies: In a marginal-littoral setting. In a cratonic interior.

The ironstone as much as 1 m thick is enclosed in claystone and sandstone.

The weathered ooids and minor pisoids are goethite and minor hematite.

Ref.: K. Alzouma and J. Trichet. Trichet et al., 1986; Lang et al., 1986.

215 – Ooidal ironstones

Near Agadem, Termit and Zaouzaoua in southeastern Niger as well as in the Chad Basin north of Fort Lamy in western Chad. In horizontal strata. Uneconomic deposits.

Age: Post-Middle Eocene. In the Dolle and Agadem formations (Continental Terminal) in southeastern Niger.

Major facies: Probably in alluvial or lacustrine setting in a cratonic interior.

The ooids and pisoids are enclosed in mudstone and sandstone. The weathered ooids are goethite.

Ref.: Lang et al., 1990; Faure, 1966.

216 – Say ooidal ironstone

In the Iullemmeden Basin near Dingazi and Souguera northeast of Niamey, southwestern Niger. In boreholes in horizontal strata. Has future potential.

Age: Late? Cenozoic. In Continental Terminal.

Major facies: In alluvial setting in a cratonic interior.

The ironstone from 1 cm to several m thick is enclosed in mudstone and sandstone.

The weathered ooids and minor pisoids are either goethite or hematite.

Ref.: J. Trichet. Lang et al., 1990.

Nigeria

Late Cretaceous

217 – Agbaja (also Batati and Sapke) ooidal and pisoidal ironstones

In the Agbaja Plateau in the middle Niger Basin near Lokoja in central Nigeria. In horizontal strata. In outcrops and boreholes. Uneconomic depositss.

Age : Late Cretaceous (Campanian to Maastrichtian).

Major facies: In a paralic to nearshore marine setting.

The ooids and pisoids contain goethite, hematite, kaolinite, maghemite, and magnetite, as well as some siderite and apatite.

Diagenetic effect: Maghemite and magnetite were made after burial.

Ref.: Umeorah, 1987.

Paleogene

218 – Sokoto ooidal ironstone

In the southern part of the Iullemmeden Basin near Sokoto, northwest Nigeria. In horizontal strata. An uneconomic deposit.

Age: Middle? Eocene. At the top of the Gamba Shale about 3 m thick.

Major facies: A shallow sea.

The ooids are goethite and minor hematite.

Ref.: Kogbe, 1981; Lang et al., 1986.

Norway

Early Ordovician

219 – Ooidal ironstones

In several localities near Oslo in the south and Hamar 100 km to the north. In folded and faulted rocks. Uneconomic deposits.

Age: Early Ordovician (late Arenigian).

The ironstones are in a carbonate sequence, and are above a bioclastic limestone and below a bioclastic marlstone. They are transitional below and above in the south but unconformable in the north.

Major facies: An offshore marine setting in a cratonic interior.

The ironstones are generally less than 0.5 m thick and locally in beds less than 2 cm thick or absent.

The ooids are nearly unweathered in the north and mostly weathered in the south. The unweathered ooids are chamosite. The matrix of clay minerals and fine quartz includes calcite, dolomite, chlorite, illite, phosphorite, and glauconite.

Diagenetic effect: Early – burrowing. Later – replacement and recrystallization.

Average Fe_2O_3 content: less than 11 %.

Ref.: N. Spjeldnaes.

Early and Middle Jurassic

220 – Offshore ooidal ironstones

In marine boreholes in the Hallenbanker west of the coast at Bindal, west-central Norway, and the Veslefrii field west of the coast at Gulen, south-west Norway. Several uneconomic deposits.

Age: Early Jurassic – Sinemurian (Stratfjord Formation), Pliensbachian (Tilje and Intra-Dunlin formations), Toarcian (Tofte Formation), and Middle Jurassic – Bajocian–Bathonian (Garn Formation).

Major facies: A nearshore shallow marine setting.

The ooids are generally less than 9–20 % of the local high porosity sandstone within the formations.

The ooids are either chamosite or mixed-layer berthierine-chamosite.

Diagenetic effect: Part of the berthierine was changed to chamosite.

Ref.: Ehrenberg, 1993.

Oman

Late Cretaceous

221 – Ooidal ironstone

In the Semail Gap area of the Oman Mountains in the central Oman. In folded and faulted strata. An uneconomic deposit.

Age: Late Cretaceous (Turonian). At the Wasia-Aruma contact.

Major facies: A shallow sea on a platform.

The ferruginous ooidal ironstone lies on hardground, with Wasia carbonates below and Sayja calcareous mudstone above the ironstone.

Ref.: Robertson, 1987.

Pakistan

Middle Jurassic

222 – Samana Suk ooidal ironstone

In the Salt Range, northern Pakistan. In folded meta-sedimentary rocks. Uneconomic deposit.

Age: Middle Jurassic (middle Callovian). In sandy Samana Suk Formation 50 m thick; underlain by the Shinawari Formation (Toarcian) and overlain by the Chichall Formation (Kimmeridgian).

Major facies: In a shallow sea.

Ref.: F. B. Van Houten. Gaetani and Garzanti, 1991.

Paleogene

223 – Langrial ooidal ironstone

In the southern Hazara district in northern Pakistan; about 50 km north of Rawalpindi and 30 km south of Abbottabad. In folded metasedimentary rocks. An uneconomic deposit.

Age: Early Paleogene (early Paleocene). In the Hangu Formation up to 6–7 m thick; overlying the late Cretaceous Nara sandstone and sandy limestone and underlying Lockhart Limestone (Paleocene).

Ironstone lies in reddish brown to greenish gray ferruginous sandy mudstone. Upper and lower parts of many of the ironstones are lateritic whereas the middle parts are largely unweathered chamosite as well as ferric oxide.

Average chemical composition (%): Fe_2O_3 9–50, SiO_2 9–60, Al_2O_3 5–30, $CaCO_3$ 1–12.

Diagenetic effect: Probably berthierine was changed to chamosite and ferric oxide.

Ref.: Khan and Ahmed, 1966; Maynard, 1986.

Philippines

Neogene

224 – Ooidal ironstones

In the Cagayan valley in the northeasternmost Luzon Island. In faulted strata. Uneconomic deposits.

Age: Late Neogene (Pliocene). In a matrix of mudstone underlain by sandstone.

Major facies: A shallow sea in the Pacific orogenic rim.

The average chemical composition (%): Fe 54.7, Mn 0.7, SiO_2 6.68, Al_2O_3 0.225, P_2O_5 0.039.

Ref.: Krishnan, 1955.

Poland

Ordovician

225 – Ooidal ironstones

In the Lysogory region in the northern area and in the

Brzeziny borehole near Moravica in the Kielce area in the southern area of the Holy Cross Mountains, in the borehole in northeast Mazury area, and in boreholes in the north-central peri-baltic depression in Poland. In folded strata. Uneconomic deposits.
Age: Middle Ordovician in Brzeziny Beds, the Jeleniow Beds (Lysogory area), and boreholes in the Leba facies of the north-central coast. In the latest Middle or earliest Late Ordovician in the Pomorze Beds in the Mazury area.
Major facies: Marine sediments of an offshore shelf.
The ooids are mostly hematite and chamosite.
Ref.: Tomczykowa and Tomczyk, 1970.

Middle Devonian

226 – Dabrowa and Miedzana Góra ooidal ironstones
In the vicinity of Kielce in the southern part of Holy Cross Mountains, in south-central Poland. In folded strata. Uneconomic deposits.
Age: Middle Devonian.
Major facies: A marine setting.
The weathered ooids contain goethite, pyrite, and siderite.
Average chemical composition (%): Fe 38–42, MnO 2.2, SiO_2 10–18.
Ref.: Osika, 1977/1978.

227 – Ooidal ironstones
In boreholes in the north-central peri-baltic depression in northern Poland. Uneconomic deposit.
Age: Middle Devonian.
Ref.: Ushakov et al., 1984.

Early Jurassic

228 – Lobez and Gardzin ooidal ironstones
In the Pomeranian Anticline northeast of the Holy Cross Mountains in central Poland. In folded strata. Abandoned mines.
Age: Early Jurassic (Pliensbachian).
Major facies: A marine setting. As many as 8 ironstones 50 to 80 cm thick are composed of ooids of chamosite (or berthierine) and siderite.
Average chemical composition (%): Fe 32.4, MnO 0.74, SiO_2 14, Al_2O_3 10.4, CaO 2, MgO 1, P_2O_5 0.08.
Ref.: Osika, 1968, 1977/1978.

229 – Konskie-Starachowice ooidal ironstones
In the Holy Cross Mountains near Konskie, Starachowice, and Przysucha in central Poland. In folded strata. Abandoned mines.
Age: Early Jurassic (Pliensbachian).
Major facies: A nonmarine-lacustrine? setting.
Three ironstone beds with total thickness 25–94 cm.
Chemical composition (%): Fe 29.5, Mn 0.74, SiO_2 19, Al_2O_3 10, CaO 1.0, MgO 1.2, P 0.08, S 0.3.
Ref.: Osika, 1968, 1977/1978.

230 – Opoczno ooidal ironstone
Opoczno area south of Warsaw and north of the Holy Cross Mountains in central Poland. In folded strata. An uneconomic deposit.
Age: Early Middle Jurassic (Aalenian).
Ref.: Osika, 1968, 1977/1978.

231 – Czestochowa and other ooidal ironstones
In the Czestochowa area near Klobuck northwest of the Holy Cross Mountains , in the area of Kalisz and Jarosin in the Subsudetic Monocline, and near Leczyca in the Kuyavian–Pomeranian Anticline in central Poland. In folded strata. Abandoned mines.
Age: Middle Jurassic (Bathonian). In the Kuyavian sequence.
Major facies: A marine setting.The ooids consist of chamosite (or berthierine) and siderite.
Chemical composition (%): Fe 31–37.5, SiO_2 5.6–8, CaO and MgO 6.1–8.
Ref.: Osika, 1968, 1977/1978.

Early Cretaceous

232 – Ooidal ironstones
In the vicinity of Radom and Ilza north of the Holy Cross Mountains in central Poland. In folded strata. Uneconomic deposits.
Age: Early Cretaceous (Valanginian–Hauterivian).
Major facies: A marine setting. As many as 3 layers of ironstones lie in mudstone and sandstone, with some glauconite. The thickness of a layer is 35 cm.
Ref.: Osika, 1968, 1977/1978.

Portugal

Early and Late Ordovician

233 – Ooidal ironstones
In Moncorvo and Serra-do-Marao near Vila Real, and Guadramil near Braganca in Tras os Montes Province, northern Portugal. In folded and faulted strata. Abandoned mines and uneconomic outcrops.
Age: Early and Middle Ordovician (Arenigian–Llanvirnian). Near the top of the Quartzito Armoricano Formation.
Major facies: An offshore shelf, probably during regional transgression, in a cratonic interior or rifted basin. The cross-bedded and burrowed ironstones are as much as 6–8 m thick, interbedded with siltstone and sandstone.
The ooids consist of goethite, green clay, and siderite, or hematite, magnetite, and martite where metamorphosed.
Ref.: T. P. Young. Young, 1992.

234 – Ooidal ironstones
In Valongo, Buçaco, Domes, and Amendoa near Porto and in Louredo near Coimbra in Douro and Beira provinces,

northern Portugal. In folded and faulted strata. An uneconomic deposit.

Age: (1) early Middle Ordovician (Llanvirnian): In the base of the Valongo Formation and in equivalent strata in the Breja Fundeiro Formation farther south. (2) early Late Ordovician (Caradocian): In the base of the Louredo Formation and the base of the Sobredo Formation, and in the base of Cabeço do Pao Formation farther south. (3) late Late Ordovician (Ashgillian): In the base of the Leira Member of the Porto da Santa Ana Formation and the Serra da Cadaveira Member of the Cabeço do Pao Formation farther south.

Major facies: An offshore shelf during regional transgression in a cratonic interior.

The ironstones lie disconformably above black mudstone and transitionally below sandstone. The ironstone is 30 cm to 3 m thick. The outcrops are weathered.

The ooids are mainly chamosite. The matrix is green clay with phosphatic intraclasts near the base.

Ref.: T. P. Young. Young, 1989b; 1992.

Romania

Paleogene

235 – Capuş ooidal ironstone

Along the Somes Valley in northwestern Transylvanian Basin, Capuş Mare County in northern Romania, and 26 km west of Cluj. In folded and faulted sedimentary deposits. An abandoned mine.

Age: Middle Eocene (Lutetian). In the lower marine formation, largely yellow limestone with glauconite. *Anomia* and *Eupatagus* below the ironstone, *Gryphaea eszterhazy* within the ironstone, and *Nummulites perforatus*, *N. striatus*, and *N. variolarius* above it.

Major facies: A paralic to shoreline marine setting in a back-arc basin.

Six km of cross-bedded ironstone in the northern part of the deposit is 0.5–1 m thick whereas in the southern part 4–10 m thick. The ooids are generally ellipsoidal and form 5 to 25 percent of the detritus.

Major minerals are goethite and hematite as well as glauconite. Minor minerals are calcite, siderite, magnetite, and sulfide.

Typical chemical composition (%): Fe_2O_3 33, FeO 1.2, MnO 0.15, SiO_2 10.2, Al_2O_3 3, CaO 16.2, MgO 1.8, P_2O_5 0.5.

Ref.: Hadnagy Arpad. Ianovici and Kräutner, 1977/1978.

Russia – European part

Middle? Ordovician

236 – Ooidal ironstone

In the Bagan borehole in the Khoreyver Basin in the Timan-Pechora province (vicinity of the lower Pechora River) in the west of the northern Ural Mountains in northeastern Russia. An uneconomic deposit.

Age: Middle? Ordovician.

Major facies: In a marine setting.

The ironstone is enclosed in fine-grained siliciclastic and dolomitic sequence.

The ooids are pyrite.

Diagenetic effect: Probably the pyritic ooids were originally ferrous silicate.

Ref.: Kushnareva and Rasskarova, 1978.

Middle and Late Devonian

237 – Ooidal ironstones

In the Khoper district near Voronezh and in North Onega near Volgograd in southern Russia, and in Pashiya sequence 100 km northwest of Nizhniy Tagil in east-central Russia. In folded and faulted strata. These ironstones are abandoned or uneconomic deposits.

Age: Middle and Late Devonian. Khoper is Middle and Late Devonian; the others are Late Devonian.

Major facies: In a marine setting.

The ironstones are 0.5 to 8 m thick in sandstone and mudstone. The ooids are hematite, chamosite, and siderite.

Chemical composition of the rich Pashiya ore (%): Fe 49.6, SiO_2 12.9, Al_2O_3 6.5, CaO 1–2, P 0.86.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

Early and Middle Jurassic

238 – Malka ooidal ironstone

In the northern slope of the Greater Caucasus, south of Pyatigorsk and northwest of Nalchik, in southernmost Russia. In horizontal strata. Abandoned and uneconomical deposits.

Age: Early and Middle Jurassic.

Major facies: In marine setting. The ironstone is about 3.5 to 5 m thick, and it is in sandstone and mudstone.

The ooids consist of goethite, berthierine, and siderite.

The chemical composition (%): Fe 32.3, SiO_2 35, Al_2O_3 14.9, P 0.5, Ni 0.6.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

Late Jurassic

239 – Lipetsk ooidal ironstone

Near Lipetsk, Orel, and Voronezh, about 200 km southeast of Tula, in central Russia. In horizontal strata. Currently exploited.

Age: Late Jurassic.

Major facies: An alluvial deposit.

The ironstone is in average about 1.6 m thick with a maximum of 4–5 m. The ooids and pisoids contain goethite.

The chemical composition (%): Fe 39–44, SiO_2 17–24, P 0.4.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

Late Cretaceous

240 – Khoper ooidal ironstone

In Hopiorskiy region near Urupinsk and southeast of Voronezh, south-central Russia. In horizontal strata. An uneconomic deposit.

Age: Late Cretaceous (Turonian to Senonian).

Major facies: In a marine setting in a cratonic interior.

The ironstone is 3 cm to 3 m thick.

The ooids are goethite and minor siderite and berthierine.

Chemical composition (%): Fe 39.4–41.8, SiO_2 20–30, CaO 0.65–5.9, MgO 0.2–0.24, Mn 0.28–1.5, P 0.54–2.08.

Ref.: E. V. Golubovskaya and D. I. Pavlov. Zitzmann, 1977/1978e.

Russia – Asian part

Middle Ordovician

241 – Ooidal ironstone

East of Igarka in the Kureyka River valley in the eastern Tunguska syncline on the northwestern Sibirian platform. In gently folded strata. An uneconomic deposit.

Age: Middle Ordovician.

Ref.: Markov, 1971.

Middle Devonian

242 – Ooidal ironstone

On October Revolution Island, northernmost central Siberia. Un uneconomic deposit.

Age: Basal Middle Devonian. In the Brodovsky Beds in the upper part of the Albanov Formation.

Ref.: Matukhin et al., 1981.

Early and Middle Jurassic

243 – Ooidal ironstones

In the Zhigansk region of the middle Lena Basin, central Siberia. In boreholes. Possible future potential.

Age: Middle Jurassic (Aalenian) and minor Early Jurassic (Toarcian). In a sandy mudstone in a coal-bearing sequence.

Major facies: Shallow marine environment.

The green ironstones are 2 to 15 m thick, and contain some pyrite.

The ooids are spherical or ellipsoidal. They are composed of "chamosite".

Chemical composition (%): FeO 15.2–17, Fe_2O_3 6.4–7.3, MnO 0.6, SiO_2 25.1–43, Al_2O_3 6.3–11.2, CaO 4.1–20.1, MgO 1.8–2, TiO_2 0.4–0.8.

Ref.: Dubar, 1959.

Early to Late? Cretaceous

244 – Serov and Marsyat ooidal ironstones

50 km north of Serov in the eastern slope of the Middle Urals, westernmost central Siberia. In horizontal strata. Future potential.

Age: Late Early Cretaceous (Albian) to Cenomanian? In an Early Cretaceous sandstone and mudstone.

Major facies: In a marine shoreline setting during prograding in a foreland basin. The quartz and clay-rich ironstones are 0.5 to 2 m thick, overlain by Santonian sandstone or marine Paleocene mudstone.

The ooids and pisoids contain goethite, berthierine, and siderite, with glauconite and fossil plant remains.

Average chemical composition (%): Fe 26.5, SiO_2 34.9, Mn 0.83, P 0.66.

Ref.: D. I. Pavlov. Zitzmann, 1977/1978e.

Late Cretaceous

245 – Mugay ooidal ironstone

Nine km south of Mugay station and 110 km northeast of Nizhniy Tagil on the eastern slope of the Middle Urals, westernmost central Siberia. In horizontal strata. Future potential.

Age: Late Cretaceous (Cenomanian). In a sequence of sandstone and mudstone above Early Cretaceous deposits and below glauconitic sandstone and Senonian mudstone.

Major facies: Shallow sea.

The ironstone is 0.7 to 2.7 m thick. The ooids are goethite, berthierine, and pyrite, with quartz and glauconite.

Chemical composition of average ore (%): Fe 24.78, Mn 0.57, SiO_2 38.32, Al_2O_3 7.02, CaO 2.03, MgO 1.38, P 0.2, S 0.65, Ti 0.16.

Ref.: Zitzmann, 1977/1978e.

246 – Sinara-Techa ooidal ironstones

In an area 45 km east-southeast of Kamensk-Uralskiy and 110 km northeast of Chelyabinsk in the westernmost central Siberia. In horizontal strata. An uneconomic deposit.

Age: Late Cretaceous (Santonian to Campanian).

Major facies: A shallow sea.

The ironstone types are limonite, siderite-limonite, and limonite with glauconite. The ooids are goethite, siderite, and glauconite, with quartz.

The average chemical composition (%): Fe 31.6, SiO_2 32.5, Al_2O_3 4.4, CaO 2.1, MgO 1.8, P 0.5, Ti 0.13.

Ref.: Zitzmann, 1977/1978e.

Late Cretaceous–Early Paleogene

247 – Bakhchar, Narym, Kolpashevo, Tym, and Chigorin ooidal ironstones

Near Parlodar, Tomsk, and Kolpashevo in western central Siberia. In horizontal strata. Future potential.

Age: Late Cretaceous to Early Paleogene (early Eocene). Narym – Turonian or Senonian; Kolpashevo and Bakhchar – Maastrichtian; Tym – Paleocene; Chigorin – Early Eocene.

Major facies: Shallow sea in a cratonic interior.

Cross-bedded and disrupted ironstones are in sandstone and mudstone, with conformable or erosional contacts. The thickness of the ironstones: Narym 12 to 16 m, Kolpashevo 8 to 25 m, Bakhchar up to 26 m, and Chigorin (with glauconite peloids) 1 to 1.5 m.

The ooids and rare pisoids are largely goethite and berthierine, with phosphatized plant remains.

Ref.: D. I. Pavlov. Nagorskiy, 1981.

Paleogene

248 – Loshchinsk ooidal ironstone

Near Omsk in the western central Siberia. In horizontal strata. In outcrops and mine. A future potential.

Age: Paleogene (early? Oligocene).

Major facies: May be an alluvial deposit.

Cross-bedded and disrupted ironstone in sandstone and mudstone with plant remains. The ironstone is 3 to 6 m thick.

The ooids are composed of goethite.

Diagenetic effect: Chlorite and siderite were changed to goethite.

Ref.: D. I. Pavlov.

Saudi Arabia

Devonian

249 – Ooidal ironstones

Near Sakaka in the north-central Saudi Arabia. Uneconomic deposits.

Age: Devonian. In the Tawil Sandstone of the upper member of the Tabuk Group and the overlying Al Jauf Formation of sandstone and carbonate.

Ref.: Smith et al., 1984.

Middle–Late Triassic

250 – Ooidal ironstones

In the central Riyadh region. Uneconomic deposits.

Age: Middle and Late Triassic. In the Middle Triassic Jilh sandstone, shale, and carbonate, and in the Late Triassic Minjur sandstone and shale.

Major facies: An inland sea with associated coal.

Ref.: Smith et al., 1984.

Middle Jurassic

251 – Ooidal ironstones

In the Qasim, Aflaj, and Al Arid areas in the central Riyadh region of Saudi Arabia. Uneconomic deposits.

Age: Middle Jurassic. In the Dhruma sandstone, shale, and carbonate in the Riyadh area, and in equivalent beds in the Aflaj area farther south.

Major facies: An inland sea with associated coal.

Aflaj chemical composition (%): Fe 38, SiO_2 34, Al_2O_3 2.1, P_2O_5 0.17.

Ref.: Collenette and Grainger, 1994.

Early Cretaceous

252 – Ooidal ironstones

In the Riyadh area in central Saudi Arabia. Uneconomic deposits.

Age: Early Cretaceous (Barremian to Aptian). In the Riyadh sandstone and shale.

Major facies: May be nonmarine, with coal.

Ref.: Smith et al., 1984.

Late Cretaceous

253 – Ooidal ironstone

In the Bida Basin in the north-central Saudi Arabia. An uneconomic deposit.

Age: Late Cretaceous (Cenomanian or Turonian). In the siliciclastic Wasia Formation with coal.

Ref.: Smith et al., 1984.

254 – Ooidal ironstones

In the Haddat Ash Sham about 60 km northeast of Jeddah, west-central Saudi Arabia. In horizontal strata. Uneconomic deposits.

Age: Late Cretaceous (Maastrichtian). Ironstones are in the lower El Hegre Member (80 m) and the overlying Borma Member (42 m) of the Haddat Ash Sham Formation, and in the lower member of the overlying Usfan Formation (92 m).

Major facies: A marine tidal flat.

The several ironstones are from 0.3 to 1.5 m thick, and are associated with sandstone and mudstone.

Ref.: Bahafzalla et al., 1983.

Paleogene

255 – Wadi Fatima ooidal ironstone

In Wadi Fatima about 45 km east of Jeddah, in west-central Saudi Arabia. In folded and faulted strata. Currently exploited for cement industry.

Age: Early Eocene (Ypresian). In the middle of the Shumaysi Formation of 80–200 m of sandstone and claystone with some glauconite, overlying the Precambrian rocks.

Major facies: A marine or paralic setting during regional transgression in a passive margin, or possibly in a lake.

Two ironstones 1.5 and 4.5 m thick have a thin shale above and below. Ooids and pisoids consist of goethite and hematite, with sulphide in fresh ore. The nuclei are quartz.

The chemical composition (%): Fe 46.2, Mn 0.39, SiO_2 12, P 0.68, S 0.14.

Ref.: J. Petránek. Moltzer and Binda, 1981.

Slovakia

Triassic-Jurassic

256 – Oravice ooidal ironstone

In northern Slovakia, near Trstená, about 60 km northeast of Martin. The outcrops occur along a 180 km southward trend. In folded strata. Abandoned mine. Uneconomic deposit.

Age: Late Triassic (Rhaetian) and Early Jurassic. In the Krížná nappe in a largely fossiliferous limestone sequence.

Major facies: A marine shoreline or barrier bar with regional transgression of a passive margin.Ironstone in limestone is 0.3 to 1.5 m thick, between strata of shale and limestone. It is unweathered, and the ooids are commonly plastically deformed.

Ooids are mainly hematite, chamosite, calcite, and siderite, with minor goethite, pyrite, and phosphorite, and rare illite.

Diagenetic effect: Chamositic ooids were changed to hematite and siderite.

Average chemical composition (%): Fe_2O_3 16–18.5, MnO 0.69, SiO_2 5.1, Al_2O_3 0.50, CaO 38, MgO 3.9, Na_2O 0.98, K_2O 0.37, P_2O_5 0.2.

Ref.: M. Mišík. Kúšik, 1967.

Spain

Early-Middle Ordovician

257 – Ooidal ironstones

Near Badajos in the Ossa Morena in the Estremadura Province, southwestern Spain. In folded strata. Uneconomic deposits.

Age: Late Early and Middle Ordovician.

Ref.: Gutiérrez-Marco et al., 1984.

Middle Ordovician

258 – Coto Wagner, Coto Vivaldi and other ooidal ironstones

In the region of Ponferrada to north of Lugo, in Leon and Galicia provinces, northwest Spain. In folded strata. Abandoned as well as currently exploited mines.

Age: Middle Ordovician (Llandeilian). In the Luarca sandy shale.

Major facies: A shallow sea.

The ironstones are as much as 10 m thick.

The ooids are hematite, goethite, chamosite, siderite, magnetite, and some pyrite.

Diagenetic effect: Magnetite resulted from contact metamorphism.

Average chemical composition (%): Fe 52.2–52.9, Mn 0.17–0.36, SiO_2 9.5–9.8, Al_2O_3 6.8–7.2, MgO 0.78–0.88, P 0.78–0.84.

Ref.: Gutiérrez-Marco et al., 1984; Zitzmann and Neumann-Redlin, 1977/1978.

259 – Ooidal ironstones

In an area just south of Cabo Penas north of Oviedo, in the west of Bibaderella, and in the west and southwest of Oviedo in Asturias Province, north-northwest Spain. In folded strata. Uneconomic deposits.

Age: Middle Ordovician (Llandeilian). Two ironstones lie in the Luarca Formation in the central Asturias and in the Sueve Formation in the eastern Asturias.

Major facies: A nearshore marine setting.

In the lower part of the mudstone sequence overlying a sandstone rich in volcanic material.

Ref.: C. Aramburu. Gutiérrez-Marco et al., 1984.

Middle-Late Ordovician

260 – Lower and Upper ooidal ironstones

In Fombuena and Luesma area in the Eastern Iberian Chains, about 60 km south of Zaragoza, central-northeastern Spain. In folded strata. Abandoned mines.

Age: The Lower ironstone is of Early Ordovician (Llanvirnian) age and lies at the base of mudstone and sandstone directly above the Armorican Quartzite.

The Upper ironstone of Late Ordovician (Caradocian) age lies above a thick sandstone and below mudstone.

Major facies: A shallow marine setting.

The ironstones are 0.5 to 3 m thick.

Ref.: Carls, 1975.

Late Silurian

261 – Ooidal ironstones

About 30 km southwest of Oviedo, Asturias Province, north-northwest Spain. In folded strata. Uneconomic deposits.

Age: Late Silurian. Several thin beds in the Furada Formation.

Major facies: A shallow sea.

The ironstones occur in sandstones interbedded with mudstone. The ooids are ferruginous.

Ref.: C. Suarez di Centi. Sanchez de la Torre et al., 1984.

Early Devonian

262 – Ooidal ironstones

Near Nogueras and Loscos 60 km south of Zaragoza in the Eastern Iberian Chains, central-northeast Spain. In folded strata. Uneconomic deposits.

Age: Early Devonian (Lochkovian). In the middle and upper members of the Luesma Formation which is 220 m of sandstone and mudstone.

Ref.: Carls and Gandl, 1967.

Middle Devonian

263 – Llumeres and other ooidal ironstones

South of Cabo Penas, about 30 km north of Oviedo and 20 km northwest Gijón, and southwest of Oviedo, Asturias Province, north-northwest Spain. In folded strata. Abandoned mines.

Age: Middle Devonian (Givetian). In Naranco Formation.

Major facies: A marine nearshore setting.

Five or six beds of ironstones in a total thickness of 8 to 12 m are in a sandstone and mudstone.

The Llumeres ooids are hematite, goethite, chamosite, apatite, and phosphate.

Chemical composition of the ore (%): Fe 51.2–52.1, Mn 0.11, SiO_2 13–15, Al_2O_3 4–7.5, CaO 1.6–1.9, MgO 0.4–0.6, P 0.64.

Ref.: J. C. Garcia-Ramos. Zitzmann and Neumann-Redlin, 1977/1978.

Early Jurassic

264 – Moron de Alhama ooidal ironstone

In the Sierra de Espuna west of Alhama de Murcia in Murcia Province, southeast Spain. In folded strata. An uneconomic deposit.

Age: Early Jurassic (Toarcian).

Major facies: A marine offshore setting.The ironstone a few m thick is condensed in a carbonate sequence.

The ooids consist of goethite.

Ref.: Geyer and Hinkelbein, 1974.

Middle Jurassic

265 – Lower and Upper Boundary ironstones

In Teruel and Valencia provinces in the Eastern Iberian Chains in central-northeastern Spain. In folded strata. Uneconomic deposits.

Age: Middle Jurassic. Late Aalenian, early Bajocian, and Callovian beds in a carbonate sequence.

Major facies: A marine offshore setting.

The ironstones occur in hardgrounds with reduction or interruption of sedimentation. They are up to 1 m thick and the ooids are largely goethite.

Ref.: Hinkelbein, 1975.

Sudan

Early/Late Cretaceous transition

266 – Ooidal ironstones

Near Shendi and Atbara along the Nile River 200 km northeast of Khartoum in northeastern Sudan, and at El Fula near El Muglad in central Sudan. In horizontal strata. Uneconomic deposits.

Age: Near the Early/Late Cretaceous transition – Cenomanian (Shendi Formation) or Albian-Cenomanian (El Fula in the Tagabo Formation).

Major facies: Alluvium and paleosols.

The ironstones are up to 80–90 cm thick in the Shendi region and 20–40 cm thick in the Fula region.

The ooids are goethite, minor hematite, and kaolinite.

The chemical composition of nonmarine ooids (%): Fe 68.72, MnO 0.48, SiO_2 11.78, Al_2O_3 4.93, CaO 0.51, MgO 0.36, P_2O_5 1.01.

Ref.: Schwarz and Germann, 1993.

Late Cretaceous

267 – Abyad Plateau ooidal ironstone

In Abyad Plateau 250 km south of the Egypt border in north-central Sudan. In horizontal strata. An uneconomic deposit.

Age: Late Cretaceous (Turonian to Coniacian). In the wadi Hower Formation.

Major facies: A shallow sea.The ooids are mostly goethite and minor hematite and kaolinite.

Average chemical composition (%): Fe 58.17, MnO 1.33, SiO_2 17.53, Al_2O_3 5.38, CaO 4.46, MgO 0.77, P_2O_5 2.24.

Ref.: T. Schwarz. Schwarz and Germann, 1993.

268 – Wadi Halfa and other ooidal ironstones

Along the Nile River from Aswan in southeastern Egypt to the Wadi Halfa at the northernmost Sudan border. In horizontal strata. Uneconomic deposits.

Age: Late Cretaceous (Coniacian to Santonian).

Major facies: A marginal marine setting.

The Wadi Halfa ironstones are 0.3–0.4 and 0.7 m thick and contain goethite and minor hematite and kaolinite.

Ref.: T. Schwarz. Schwarz and Germann, 1993.

Sweden

Early Ordovician

269 – Siljan ooidal ironstone

In the north of Lake Siljan, Dalarna Province, central Sweden, surrounding the Siljan ring structure. In folded and faulted strata. An uneconomic deposit.

Age: Late Early Ordovician (Kundan Stage). The 6–8 m Holen Limestone of skeletal sand is underlain disconformably by the Lanna Limestone and overlain by the Middle Ordovician Segerstad Limestone.

Major facies: A carbonate sea.

Goethitic ooids are present in the lower part of the Holen Formation whereas chamosite ooids are present in the upper part. Chamosite ooids persist until the Middle Ordovician Skagen Limestone.

Ref.: Jaanusson, 1982.

270 – Öland ironstones

In a belt about 30 km long near Byrum, northern Öland island, eastern Sweden. Several uneconomic deposits.

Age: Late Early Ordovician. In the lower Holen Limestone (Kundan Stage).

Major facies: A nearshore marine setting.

The ooids are goethite, hematite, and chamosite associated with phosphatic ooids. Some ooids are spastoliths.

Diagenetic effect: Berthierine probably was changed to chamosite. Then in most cases the goethite and later hematite were made after the chamosite was produced.

Ref.: Sturesson, 1986.

Middle Ordovician

271 – Ekon ooidal ironstones

In the Ekon and Smedsky Gard boreholes, near Motal, Östergötland in the southeast-central Sweden. In folded strata. Several uneconomic deposits.

Age: Middle Ordovician (Viruan Stage). Ironstones occur in the lower Seby Limestone (more than 1.2 m), in the upper Folkeslunda Formation (2.7 m), in the basal and middle Furudal Limestone (12 m) and in the lowest part and several beds in the upper part of the Dalby Limestone (19 m).

The ooids are chamosite and goethite.

Major facies: A shallow marine setting.

Ref.: Jaanusson, 1962.

Middle-Late Ordovician

272 – Ooidal ironstones

In the Gullhogen quarry on the east slope of Mount Billington and at Kunnekulle (Hallekis quarry) near Skovdes, Västergötland in south-central Sweden. Several uneconomic deposits.

Age: Early Ordovician (Llanvirnian and Llandeilian) and early Late Ordovician (Caradocian).

The ironstones occur in places in the Early Ordovician Vamb Limestone, only about 10 cm thick, in the basal part of the Llandeilian Gullhogen Formation (including the lower Skovde Limestone), 12 m thick, of largely mudstone, and in the upper Dalby Limestone, 12 m, of Late Ordovician age (Caradocian).

The ooids are associated with phosphatic ooids and some are spastolithic. The ooids are composed of goethite, hematite, and chamosite.

Diagenetic effect: Volcanic ash associated with and just below the ironstones suggests that it supplied the source material that eventually made the chamosite ooids.

Chemical composition from Vamb Limestone (%): Fe_2O_3 43.2, SiO_2 27.8, Al_2O_3 10.8, CaO 0.2, MgO 4, P_2O_5 2, TiO_2 0.8.

Ref.: Jaanusson, 1982; Sturesson, 1989,1992.

Jurassic

273 – Nordväst-Skäne ooidal ironstone

In the area of Hälsingborg, Höganäs, Angelholm, and near Eslov, about 45 km southeast of Hälsingborg in northwest Scania in southern Sweden. In folded strata. Several uneconomic deposits.

Age: Early Jurassic or later Jurassic. Thin beds of ironstones are in the Höganäs Sandstone.

Major facies: A shallow marine setting.

The ironstone zone is 2 to 20 m thick. The ooids contain various amounts of chamosite, goethite, hematite, and siderite.

The average chemical composition in the richer parts: Fe 35 %, P_2O_5 0.45 %.

Ref.: Frietsch, 1977/1978.

Switzerland

Middle and Late Jurassic

274 – Ooidal ironstones

Around Grenchenberg near Solothurn (northeastern Jura Mts.), in southeast foot of Glarnisch Range near Glarus, in Herznach near Aarau (east Jura Mts.), in Erzegg near Lucerne, near Chamoson in Valais Canton (southwest Switzerland), and in Schellenbrücke near Aarau (east Jura Mts.). In horizontal or folded and faulted strata. Abandoned mines or uneconomic outcrops.

Age: Middle and Late Jurassic. Grenchenberg: Late Aalenian to Early Bajocian; Grenchenberg: Middle Bajocian; Glarus: mainly Bathonian; Aarau and Erzegg: Callovian; Chamoson: Callovian; and Schellenbrücke; Oxfordian.

Major facies: An offshore shelf during regional transgression in a passive margin. The ironstones are enclosed below and above silty and sandy bioclastic limestones or marly sandstones and shale or marlstone. Grenchenberg, Glarnisch, and Schellenbrücke ironstones are as much as 80 cm thick; the others are as much as 7 m thick. Most of them are burrowed.

The ooids consist of goethite, hematite, berthierine and chamosite, and minor magnetite in Erzegg.

Diagenetic effect: Berthierine was changed to chamosite (Erzegg) and to goethite, hematite, and magnetite (Erzegg).

The chemical composition (%) at Chamoson: FeO 30.89, Fe_2O_3 1.22, SiO_2 24.42, Al_2O_3 15.65, MgO 4.01, CaO 9.63.

Ref.: R. Burkhalter, S. Franke-Dollfuss, R. Gygi, and H. R. Blasi. Blasi, 1987; Burkhalter, 1995; Delaloye and Odin, 1988; Gehring, 1989; Gygi, 1981; de Quervain and Zitzmann, 1977/1978.

Paleogene

275 – Einsiedeln ooidal ironstone

At Einsiedeln in the Schwyz Canton east of Lucerne and southeast of Zürich, in the front of the Alps.

Age: Early? Eocene.

See Paleogene of Germany.

Syria

Early Cretaceous

276 – Radjou detrital ironstone

In the Kurd Dagh 65 km northwest of Aleppo, in the northwesternmost Syria. Folded and faulted strata. Possibly a future potential.

Age: Early Cretaceous (Early Aptian).

Major facies: Shallow marine formation transgressively overlying eroded and karstified Jurassic limestone. Probably ferruginized products of weathering of Jurassic basalts and their tuffs.

Oval to subangular detrital particles mostly 1–3 mm in size consist predominantly of phyllosilicates or siderite and together with carbonate pseudo-ooids are enclosed in iron-rich matrix (hematite, goethite). Calcite, kaolinite, illite, chlorite and quartz are also present.

The ironstone is enclosed in clay and its thickness is 2.5–20 m (6 m in average).

Chemical composition (%): Fe 31.73, Mn 0.08, SiO_2 16.48, Al_2O_3 4.65, CaO 4.30, MgO 1.37, P 0.57, S 0.07, Ti 3.2.

Ref.: J. Petránek. Gabriel and Roos, 1973; Zitzmann, 1977/1978d.

277 – Zabadany ooidal ironstone

In the Zabadany and Jdeidet Yabus area 45 km west of Damascus. In folded and faulted strata. Possibly a future potential.

Age: Early Cretaceous (Late Aptian). The ironstone is overlain by Albian limestone.

Major facies: A shallow sea. In Jdeidet Yabus there are 5–8 seams with total thickness of 3 to 10 m; they alternate with sandstone, marlstone and limestone. Jdeidet Yabus ooids are goethite and the matrix is sand, clay, berthierine, siderite, and calcite.

The average iron content is 34.7 %, the composition of ooids is (%): Fe 52, Mn 0.15, SiO_2 4, Al_2O_3 4.3, Ti 0.9.

Ref.: J. Petránek. Zitzmann, 1977/1978d.

Tunisia

Early Ordovician

278 – Ooidal ironstone

In the Jeffara line in south-easternmost Tunisia. In a borehole. An uneconomic deposit.

Age: Early Ordovician (Arenigian). In the lower part of the Kasbah Leguine Formation.

Major facies: A shallow sea.

Ref.: Young, 1992.

Middle Ordovician

279 – Ooidal ironstone

In the Jeffara line in south-easternmost Tunisia. In a borehole. An uneconomic deposit.

Age: Middle Ordovician (Llanvirnian-Llandeilian). At the top of the Kasbah Leguine Formation.

Major facies: A shallow sea.

Ref.: Young, 1992.

280 – Ooidal ironstone

In the Jeffara line south-easternmost Tunisia. In a borehole. An uneconomic deposit.

Age: Middle Ordovician (Llandeilian). In the upper part of the Bir ben Tartar Formation.

Major facies: A shallow sea.

Ref.: Young, 1992.

Middle Jurassic

281 – Ooidal ironstone

Between Jebel Nara and Jebel Sidi Kralif southwest of Kairouan, central Tunisia. In folded strata. An uneconomic deposit.

Age: Middle Jurassic (Aalenian to middle Bathonian). In the middle Nara Formation of carbonate and marlstone.

Major facies: An offshore shelf in a rifted cratonic margin.

The ironstone is about 2 m thick, contains glauconitic peloids and is weathered.

The ooids and rare pisoids are composed of goethite, hematite, and calcite, with minor apatite.

Diagenetic effect: Calcite was changed to dolomite.

Ref.: M. Soussi.

Paleogene

282 – Djebel Ank ooidal ironstone

In the Saharan Atlas mountains 40 km east-southeast of Gafsa in central Tunisia. In folded and faulted strata. An abandoned mine and uneconomic outcrops.

Age: Paleogene (middle Eocene). At the top of the Ank Formation with glauconitic peloids and manganiferous and phosphatic nodules.

Major facies: A marine shoreline during regression in a passive cratonic margin.

The ironstone is unconformable above mudstone and below marlstone and limestone.

The ooids consist of goethite and minor nontronite.

Ref.: Chaabani Frej. Nicolini, 1967.

Turkey

Late Ordovician

283 – Ooidal ironstone

In northwest Anatolia between Istanbul and Zonguldak and in Bithynian Peninsula, northern Turkey. In folded strata. An uneconomic deposit.

Age: Late Ordovician (Caradocian). A chamositic ooidal bed with graptolites; in upper part of the Kurtköy sandstone and shale which is more than 300 m thick.

Major facies: In a littoral setting.

Ref.: Wolfart, 1981; Dean, 1980.

Early Silurian

284 – Ooidal ironstone

In the southeastern Bithynian Peninsula east of Istanbul, northwestern Turkey. In folded strata. An uneconomic deposit.

Age: Early Silurian.

Chamositic ooids occur in several horizons of the Kayali-Dere Member (lower Yayalan Formation) which is 100 m thick and mostly muddy sandstone. Contains brachiopods.

Major facies: A shallow sea.

Ref.: Wolfart, 1981.

285 – Ooidal ironstone

In the eastern part of the Bithynian Peninsula, east of Istanbul, northwestern Turkey. In folded strata. An uneconomic deposit.

Age: Early Silurian (upper Llandoverian).

Chamositic ooids are widespread in the shale of the Umur-Dere Member (upper Yayalan Formation) which is 15 m thick and rich in brachiopods, and overlain by the Middle Silurian Tavsan–Tepe Limestone.

Major facies: A shallow sea.

Ref.: Wolfart, 1981.

Middle Devonian

286 – Çamdag ooidal ironstone

In Sakarya Province 20 km north-northeast of Adapazari and 140 km east-southeast of Istanbul, northwest Turkey. In folded strata. A future potential ore.

Age: Middle Devonian.

Ore lies between marly limestone and calcareous sandstone, above Early Devonian sandstone and shale and below Late Devonian shale.

Major facies: A shallow sea.

The main ooids are goethite, hematite, and chamosite.

Chemical composition (%): Fe_2O_3 18–41, MnO 0.4, SiO_2 4–20.5, Al_2O_3 9–11, CaO 1.3–15, P_2O_5 0.4.

Ref.: Özkoçak et al., 1977/1978.

Ukraine

Neogene

287 – Kerch-Taman ooidal ironstones

In eastern Crimea near Kerch, southern Ukraine (and adjacent Russia). In folded rocks. A recently abandoned deposit.

Age: Neogene (middle Pliocene).

Major facies: A storm and shoreline deposit formed during regression in the late orogenic episode in the Indol-Kuban foreland basin.

The cross-bedded and burrowed ironstones are 9.5 to 30 m thick in a coarsening upward sequence of sandstone and mudstone. The ooids and pisoids are both fresh and altered. They consist of goethite, berthierine, and siderite, with minor sulfide.

Average chemical composition (%): Fe_2O_3 32–60, FeO 0–2, MnO 0.45–2, SiO_2 13–35, Al_2O_3 3–9, P_2O_5 1.9–3.

Ref.: E. V. Golubovskaya and D. I. Pavlov. Zitzmann, 1977/1978e.

288 – Dry Indol ooidal ironstone

In the Dry Indol drainage in southwestern Crimea, southern Ukraine. In folded rocks. An uneconomic deposit.

Age: Neogene (middle Pliocene).

Major facies: Alluvial setting in a delta of the Indol-Kuban foreland basin.

The ironstone is 0.1 to 0.5 m thick at the base of the Middle and Late Pliocene green clay and sand and on the eroded surface of Paleocene Maikop Formation.

The ooids consist of goethite.

Ref.: Shnyukov and Fesyunov, 1968.

United Kingdom

Early Ordovician

289 – Arenigian ooidal ironstones

In the vicinity of Aberdaron, Abersoch, and Wig on the Lleyn Peninsula southwest of Caernarforn in Gwynedd Province, northwest Wales. In folded and faulted strata. Uneconomic deposits.

Age: Early Ordovician (Arenigian). In the siliciclatic Wig Bog and younger Castellmarch formations of the Nant Ffrancon Group. They lie on Tremadocian or Precambrian rocks.

Major facies: In a regional transgression of a marine offshore shelf in a marginal basin.

The ironstones are a few cm thick, and they lie conformably above coarse sandstone and below a siltstone. The ooids are mostly ?chamosite and apatite.

Ref.: T. P. Young. Gibbons, 1989.

Early to Middle Ordovician

290 – Trygam, Hen-dy-Capel and other ooidal ironstones

Various localities near Caernarfon, in Bangor, on sides of Harlech Dome, in Gwynedd and Gwynedd Anglesey provinces, northwest Wales. In folded and faulted strata. An uneconomic deposit or abandoned mine.

Age: Latest Early to early Middle Ordovician (latest Arenigian-early Llanvirnian). In the siltstone Nant Ffrancon Group with latest Arenigian or early Llanvirnian fossils below and early Llanvirnian fossils above.

Major facies: An offshore sea during regional transgression in a marginal basin.Most of the ironstones are 1 to 5 cm thick and enclosed mainly in siltstone. The ooids and pisoids are composed variously of hematite, chamosite, and magnetite, and minor apatite. Phosphatic oncoids are locally present.

Ref.: T. P. Young. Trythall, 1989; Traynor, 1990; Young, 1992.

Middle to Late Ordovician

291 – Crossed Foxes, Tremadog, Penterfyn and other ooidal ironstones

In northwest Wales near Aberystwyth (Crossed Foxes), near Caernarfon (Tremadog), near Bangor in Gwynedd Province and in Gwynedd Anglesey Province (Penterfyn). In folded and faulted strata. An uneconomic deposit or abandoned mine.

Age: Latest Middle to early Late Ordovician (upper Llandeilian to lower Caradocian). In the silty Fron Newydd

Member of the volcanic-rich Brithion Formation on the north side of Cadair Idris, volcanic-rich Serw Formation in Arennig, in upper Nan Ffrancon Group in Tremadog and northern Snowdonia, and Caradocian fossils in the Anglesey strata below and above the Penterfyn ironstone.

Major facies: An offshore sea during a regional transgression in a marginal basin.

The ironstones are enclosed in siltstone and some are 2 m thick. Some contain pisoids as well as ooids. The ooids are composed variously of green clay, hematite, chamosite, magnetite, stilpnomelane, siderite, and sulfide. Phosphatic oncoids are locally present.

Ref.: T. P. Young. Trythall, 1989; Young, 1991, 1992.

Late Ordovician

292 – Ooidal ironstone

In Appletreeworth near Kendal in Cumbria Province, England. An uneconomic deposit.

Age: Late Ordovician (middle of Ashgillian). At the base of the carbonate Broughton Moor Formation. It is unconformable below and transitional above.

Major facies: A marine seaway.

Ref.: R. Scott. McNamara, 1979.

Early Silurian

293 – Wickwar ooidal ironstone

At Wickwar near Bristol, southwest England. In a borehole. An uneconomic deposit.

Age: Early Silurian (Wenlockian). Lies above a limestone within the Brinkmarsh Beds.

Major facies: A marine offshore shelf in a cratonic interior near the northwest margin of the Midlands microcraton.

The ironstone about 25 cm thick is underlain and overlain by dolomite.

The fresh ooids are high magnesian chamosite, with minor apatite.

Ref.: T. P. Young. Bannister and Whittard, 1945.

Late Silurian

294 – Ty Mawr and other ooidal ironstones

In southern Wales near Cardiff (Ty Mawr) and in Saudde Gorge near Llandeilo and Swansea. In folded and faulted strata. An uneconomic deposit.

Age: Early Late Silurian (early Ludlowian). Ty Mawr ironstone is 9 m above the base of the mudstone and sandstone Hill Gardens Formation. The ironstone near Llandeilo is at the top of the Ffinnant Sandstone.

Major facies: An offshore shelf during regional transgression in a cratonic interior.

Ironstones are about 1 m thick. The Ty Mawr ooids are composed of hematite with nuclei of glauconite and bioclasts.

Ref.: T. P. Young. Bassett, 1982; Waters and Laurence, 1987.

Early Carboniferous

295 – Pisoidal ironstone

In the vicinity of Menai near Bangor, northwestern Wales. In folded and faulted strata. An uneconomic deposit.

Age: Early Carboniferous (Dinantian). In the Menai Straits Formation.

Major facies: Siliciclastic marginal marine setting just below fully marine strata.

The pisoids are a brown iron mineral.

Ref.: T. P. Young. Straton et al., 1920.

Late Carboniferous

296 – Robin Hood and other ooidal ironstones

In a few km south of Leeds, west Yorkshire, and east of Carlisle southwest of Newcastle, County Durham, in northeastern England. In folded strata. Uneconomic deposits.

Age: Late Carboniferous (Namurian C and Westphalian B). In the Yoredale facies of the Coal Measures.

Major facies: A paralic setting of a sea or lake, following the deltaic progradation.

The Robin Hood ironstone is a few to several cm thick and lies just above the Swallow Wood coal seam. It is set in dark gray mudstone.

The ooids are spherical or ovoid, and they are composed of iron-rich clay, kaolinite, siderite, as well as phosphate and pyrite.

Diagenetic effect: The original iron-rich clay (chamosite?) was diagenetically replaced by other minerals.

Ref.: Dean, 1936; Scott, 1978.

Early Jurassic

297 – Frodingham, Glebe Farm, Stubton Limestones, and other ooidal ironstones

In Scunthorpe (Frodingham) and Nettleton Bottom in South Humberside Province, in Fulbeck (Glebe Farm) and in Nottingham (Stubton Limestones) in Nottinghamshire, in Robin Hoods Bay and Redcar in North Yorkshire, in central England. In horizontal strata in outcrops and boreholes. The Frodingham ironstone is mined; the rest are uneconomic deposits.

Age: Early Jurassic (Sinemurian). In the upper part of Scunthorpe Mudstone (Frodingham and Stubton Limestones ironstones), in the Brant Mudstone (Glebe Farm ironstone), in the Redcar Mudstone (Redcar and Robin Hoods Bay ironstones).

Major facies: A marine offshore shelf during a transgression in a cratonic interior.

These ironstones generally are less than 1 m thick; some are less than 10 cm. Frodingham ironstone is as much as 12 m locally.The ooids in outcrop are composed of goethite. Frodingham ooids in boreholes also contain minor berthierine, and one bed is pyritized.

Diagenetic effect: Berthierine was changed to goethite and locally to ferroan calcite and siderite.

Average chemical composition of the Frodingham ironstone (%): Fe 21, SiO_2 4–14, Al_2O_3 2–10, CaO 10–28, P 0.2–0.5, S 0.05–0.45.

Ref.: T. P. Young. Aggett, 1990; Brandon et al., 1990; Slater and Highley, 1977/1978; Young et al., 1991; Van Buchem et al., 1992; Young, 1993; Taylor and Curtis, 1995.

298 – Ardnish ooidal ironstone

On the islands of Skye and Raasay, about 80 km northwest of Fort Williams, northwestern Scotland. An uneconomic deposit.

Age: Early Jurassic (Sinemurian). In the middle of the Upper Broadford Beds.

Major facies: A marine offshore shelf in a cratonic interior within the edge of the tectonically active Hebridean basin.

The ironstone is about 0.5 m thick. The ooids are composed of berthierine and minor goethite.

Ref.: T. P. Young. Searl, 1992.

299 – Cleveland ooidal ironstone

Pecten Seam and Main seam, Two Foot seam, Osmotherley, Avicula Seam, Raisdale Seam, Stonehouse Quarry, Marlstone Rock, and other ooidal ironstones.

In Staithes (Pecten and Main Seams, Two Foot Seam, Avicula Seam, Raisdale Seam, Osmotherley) and Robin Hood's Bay in North Yorkshire, in Scunthorpe (Pecten Seam), Crosby Warren and Nettleton Bottom in South Humberside Province, in Stonehouse (Stonehouse Quarry) in Gloucestershire, and between Oxford and Northampton (Marlstone Rock) in Oxfordshire and Northamptonshire, England. In horizontal and locally faulted strata. Abandoned or uneconomic deposits.

Age: Early Jurassic (Pliensbachian). In mainly siltstone or mudstone Cleveland Formation in Kettleness Member (Pecten and Main Seams) and Perry Nob Member (Two Foot Seam, Avicula Seam, Raisdale Seam, and Osmotherley); in the Redcar Mudstone; in the Coleby Mudstone (Pecten Seam); in the Dyrham Siltstone (Stonehouse Quarry beds); and in the Marlstone Rock Formation (Marlstone Rock ironstone).

Major facies: A marine offshore shelf during retrograding in a cratonic interior.

Ironstones are mostly less than 30 cm thick. In Marlstone Rock and Pecten and Main Seam ironstones they are as much as 4 to 8 m thick.

The ooids are mostly berthierine or green clay and locally kaolinite and apatite with glauconitic pellets.

Diagenetic effect: Early calcite, siderite, and phosphatic cements. Berthierine ooids were replaced by kaolinite and calcite.

The chemical composition of the Pecten, Main, Avicula, Two Foot, and Raisdale seams is given in Whitehead et al., 1952; Young et al., 1991.

The average chemical composition (%): Fe 28, SiO_2 8–15, Al_2O_3 8–11, CaO 2–7, P 0.45, S 0.25.

Ref.: T. P. Young. Gaunt et al., 1992; Howard, 1985; Slater and Highley, 1977/1978; Van Buchem et al., 1992; Young, 1993.

300 – Ooidal ironstone

In the island of Raasay, Scotland. An uneconomic deposit.

Age: Early Jurassic (Pliensbachian).

Major facies: A marine offshore shelf.

The ironstone contains berthierine ooids.

Ref.: T. P. Young. Hallam, 1959.

301 – Rosedale, High House and other ooidal ironstones

In Rosedale near Whitby in North Yorkshire, in Wolton-under-Edge near Gloucester, and in Penhurst and Ashdown (boreholes) near London in Kent Province. In folded and faulted strata in North Yorkshire and Kent Province and horizontal strata in Gloucestershire, England. An abandoned mine in Rosedale ironstone; the rest are uneconomic deposits.

Age: Early Jurassic (Toarcian). In the silty-sandy Rosedale Ironstone Member and the High House Member of the Blea Wylie Formation.

Major facies: In a marine offshore shelf in a cratonic interior.

The cross-bedded Rosedale ironstone is disconformable below and unconformable above. It is generally less than 4 m thick but rarely to 25 m thick. The High House ironstone is transitional below and above and it is a maximum of 1.8 m thick.

The Rosedale ooids variously contain chamosite, berthierine, magnetite, calcite, hematite, and goethite. Other ooids are goethite and green clay.

Diagenetic effect: Chamosite and magnetite were produced during later diagenesis.

Ref.: T. P. Young. Rastall and Hemingway, 1949; Richardson, 1910; Young, 1993.

302 – Raasay ooidal ironstone

On the islands of Skye and Raasay, about 80 km northwest of Fort Williams, northwestern Scotland. In folded and faulted strata. An abandoned mine and uneconomic deposits.

Age: Early Jurassic (Toarcian). In a mudstone sequence.

Major facies: A marine offshore shelf in a cratonic interior. The ironstone is transitional below and disconformable above.

The ooids contain green clay and siderite and minor apatite.

Diagenetic effect: Early phosphate, calcite and siderite cements.

The average chemical composition (%): Fe 25.2, SiO_2 6.5, Al_2O_3 5.6, CaO 17.6, MgO 2.0, P 0.8, S 0.2

Ref.: T. P. Young. Slater and Highley, 1977/1978; Young 1993.

Middle Jurassic

303 – Northampton Sands, Glaisdale and other ooidal ironstones

In Corby (Cowthick Pit) near Leicester in Northamptonshire and in Glaisdale and Rosedale near Whitby in North Yorkshire, England. Horizontal and locally faulted strata.

An abandoned mine (Northampton) and uneconomic deposits.

Age: Early Middle Jurassic (Aalenian). In the Northampton Sands, in the Dogger Formation in Glaisdale Ironstone Member, and in the upper part of the Dogger Formation in Rosedale.

Major facies: Offshore shelf in a cratonic interior.

The ironstone is in sandstone and mudstone and is unconformable or transitional below and above.

The ooids contain berthierine, siderite, kaolinite, and locally pyrite in Northampton Sands and Glaisdale ironstones, and goethite and green clay in the upper part of the Dogger Formation as at Rosedale.

Diagenetic effect: Widespread siderite and calcite cement and local pyrite in North Yorkshire.

The average chemical composition (%) of the Northampton ironstone: Fe 30, SiO_2 8–18, Al_2O_3 4–8, CaO 2–10, P 0.7–1.0, S 0.1–0.9

Ref.: T. P. Young. Rastall and Hemingway, 1940, 1949; Slater and Highley, 1977/1978; Taylor 1949; Young, 1993.

304 – Ingleby ooidal ironstone

In the Thirsk area near York, England. In horizontal and faulted strata. An uneconomic deposit.

Age: Middle Jurassic (Bajocian). In the Eller Beck Formation in Ingleby Ironstone Member (lowest part).

Major facies: Offshore shelf in a cratonic interior.

The Ingleby Ironstone is disconformable below and conformable above. It consists of mudstone. The ironstone is about 0.75 cm thick but reaches up to 4 m in some places.

The ooids consist of berthierine and siderite.

Ref.: T. P. Young. Knox, 1970.

305 – Ooidal ironstone

In the Burton Bradstock area near Dorchester, England. In variously horizontal, folded, and faulted strata. An uneconomic deposit.

Age: Middle Jurassic (Bajocian). In several horizons in the carbonate Inferior Oolite.

Major facies: Offshore shelf in a cratonic interior.

The carbonate ironstone is as much as 10 cm thick and as much as 0.5 m thick in composite ironstone.

The ooids in weathering are goethite. In subsurface they are presumable berthierine.

Ref.: T. P. Young. Palmer and Wilson, 1990.

306 – Kellaways Rock and Hackness Rock ooidal ironstones

In Kellaways Rock in Scarborough and Redcliff in North Yorkshire and in Goodnestone borehole in Kent Province, and in Hackness Rock in Scarborough area in North Yorkshire, England. In folded and faulted strata. Uneconomic deposits.

Age: Late Middle Jurassic (Callovian). Kellaways Rock, Langdale Beds and Hackness Rock members of sandstone and mudstone are in the Osgodby Formation.

Major facies: Offshore shelf in a cratonic interior.

The ironstones are about 1 to 4 m thick. The ooids are berthierine and goethite.

Ref.: T. P. Young. Wright, 1967; Lamplugh et al., 1923.

307 – Ooidal ironstone

In Roof Bed of Brora Shale near Brora on the west side of Moraz Firth, eastern Scotland.

Age: Late Middle Jurassic (Callovian).

Ref.: Anderton et al., 1979.

Late Jurassic

308 – Westbury Ironstone (with *Ringsteadia*) and other ooidal ironstones

In Westbury near Swindon in Wiltshire, in Dover in Kent Province, and in Hackness near Scarborough in North Yorkshire, England. In folded and faulted strata. In a mine, outcrops, or borehole. An uneconomic deposit.

Age: Early Late Jurassic (Oxfordian). In mudstone or mixed marlstone and mudstone. In Passage Beds Member in North Yorkshire.

Major facies: Offshore shelf in a cratonic interior.

The ironstones are transitional or conformable and less than 5 m thick.

The unweathered ooids are green clay and weathered ones are goethite.

Chemical composition (%) of the Westbury ironstone: Fe 29.7–35.8, Mn 0.17, SiO_2 11–16, Al_2O_3 4.7–7.85, CaO 5.3–5.9, MgO 1.5–2.1, P 0.475, S 0.29.

Ref.: T. P. Young. Lamplugh et al., 1923; Slater and Highley, 1977/1978; Talbot, 1974, Wright. 1992.

309 – Abbotbury ooidal ironstone

In Abbotbury near Dorchester, England. In horizontal and faulted strata. Uneconomic mine and outcrops.

Age: Late Jurassic (Kimmeridgian). The ironstone overlies the Sandfoot Grit.

Major facies: Offshore shelf in a cratonic interior.

The siliciclastic ironstone is as much as 11 m thick. The ooids consist of goethite. The iron content of the ironstone is 32–36 %.

Ref.: T. P. Young. Brookfield, 1973; Jenkyns and Senior, 1991; Slater and Highley, 1977/1978.

Early Cretaceous

310 – Ooidal ironstones

In Philpots Quarry at West Hoathly and Standingpitt Farm at Worth near London in Sussex Province. Horizontal strata. An uneconomic deposit.

Age: Early Cretaceous (Valanginian). In the Tunbridge Formation and the top of the Ardingly Sandstone Member.

Major facies: Alluvial setting in a cratonic interior.

The ironstone is unconformable below and above a nonmarine sandstone. It is 10 cm thick.The ooids and pisoids are berthierine and minor goethite and pyrite.

Diagenetic effect: Ferric oxide was changed to berthierine.

Siderite was added to the cement.
Ref.: T. P. Young. Taylor, 1990.

311 – Ooidal ironstone

In Bighnowle Fam and Burwash near London in Sussex Province. In horizontal strata. An uneconomic deposit.

Age: Early Cretaceous (Valanginian). In the top of the Ashdown Beds just below the Wadhurst Clay.

Major facies: Alluvial or brackish setting during regional transgression in a cratonic interior. The coarsening-upward ironstone is about 5 cm thick. It is transitional below by non-marine sandstone and conformable above by non-marine mudstone.The ooids consist of goethite and kaolinite.

Diagenetic effect: Early depletion of iron from the centers of ooids.

Ref.: K. G. Taylor. Taylor, 1990.

312 – Claxby ooidal ironstone

Near Lincoln in Lincolnshire, England. In horizontal strata. An abandoned quarry.

Age: Early Cretaceous (Valanginian–Hauterivian). In the Claxby Formation in the Lower and Upper Claxby Ironstone members and the overlying Lower Tealby Member.

Major facies: Offshore shelf during regional transgression. The cross-bedded, burrowed and disrupted ironstone is about 4 m thick in the lower member and 1.5 m in the upper member. It consists of quartz sand and glauconitic peloids.

The weathered ooids consist of goethite with the matrix of berthierine, goethite, and siderite. The ooids in the overlying Lower Tealby Clay Member is also goethite.

Chemical compositon (%) of (a) ironstone: Fe 20–30, SiO_2 5–20, Al_2O_3 5–10, CaO 3–8, P 0.2–0.3, S 0.1, and (b) ooids: Fe_2O_3 69.5, SiO_2 5.53, Al_2O_3 4.62.

Ref.: K. G. Taylor and T. P. Young. Gaunt et al., 1992; Slater and Highley, 1977/1978.

313 – Roach ooidal ironstone

At Alford borehole and surrounding outcrops near Lincoln in Lincolnshire, England. In horizontal strata. An uneconomic deposit.

Age: Early Cretaceous (Barremian). In Fullerby Beds Formation and Roach Stone Member.

Major facies: Offshore shelf in a cratonic interior.

The siliciclastic ironstone is as much as 11 m thick.

The unweathered ooids and minor pisoids are goethite.

Ref.: T. P. Young. Gaunt et al., 1992.

314 – Seend ooidal ironstone

In Seend near Bath, England. In horizontal strata. An abandoned mine.

Age: Early Cretaceous (Aptian). In Lower Greensand Group and Seend Ironstone Formation.

Major facies: A marine setting with regional transgression and local prograding.

The cross-bedded ironstone is as much as 10 m thick and unconformable below. It has quartz sand, glauconitic and siderite cement. The weathered ooids are goethite.

The chemical composition: Fe 30–40 %.

Ref.: K. G. Taylor. Hesselbo et al., 1991; Slater and Highley, 1977/1978.

315 – Ooidal ironstone

In Billington Crossing Quarry at Leighton Buzzard in Bedfordshire, England. An abandoned mine.

Age: Early Cretaceous (latest Aptian-early Albian). In the Lower Greensand Group in the top 10–29 m of the Woburn Sands Formation.

Major facies: A marine setting during a succession of tidal sandwave complexes in a cratonic interior.

The conformable sandy ironstone consists of less than 0.5 cm laminae on foresets of several dune sets.

The ooids are composed of goethite.

Ref.: K. G. Taylor. Schiavon, 1988.

United States of America

Middle to Late Cambrian

316 – Montana ooidal ironstones

In the eastern Rocky Mountains west-central and southwest Montana. In folded strata. Uneconomic deposits.

Age: Middle Cambrian. In the upper part of the Flathead Formation.

Major facies: A marine nearshore setting.

The ironstones are a few cm to about 60 cm thick. Glauconitic peloids are locally present.

The ooids are hematitic.

Ref.: Deiss, 1936; 1939.

317 – Ooidal ironstones of north-central Wyoming

Along the east side of Big Horn River in the Wind River Canyon, north-central Wyoming. In folded strata. Uneconomic deposits.

Age: Middle Cambrian. In the lower part of the Gros Ventre Formation.

Major facies: Probably in a deltaic setting at the top of a coarsening-upward sequence in a cratonic margin.

The ironstones are a few to several cm thick, burrowed, and associated with glauconitic peloids and phosphatic brachiopods.

The ooids 0.5 to 1 mm in diameter are mostly ellipsoid in shape. They are hematite, with cores of quartz or green clay.

Ref.: D. P. Bhattacharyya and M. E. Purucker. Deiss, 1938.

318 – Ooidal ironstones of west-central Wyoming

In a ravine on the east side of Glory Mountain just east of Teton Pass, and in the Gros Ventre Range in west-central Wyoming. In folded strata. Uneconomic deposits.

Age: Middle Cambrian. In the lower Wolsey Shale Member of the Gros Ventre Formation.

Major facies: A marine setting in a cratonic margin.

Two ironstones a few cm thick are in quartz sandstone, with glauconitic burrowed sandstone and mudstone above and below.

The ooids are "hematite".

Ref.: D. P. Bhattacharyya and M. E. Purucker. Wanless et al., 1955.

319 – Bright Angel ooidal ironstones

In the eastern Grand Canyon area of northwest Arizona. In horizontal strata. Uneconomic deposits.

Age: Middle Cambrian. In the Bright Angel Shale.

Major facies: A shallow sea.

The ironstones 10 to 15 cm thick occur in several zones of top of herring-bone galuconitic sandstone.

The ooids and peloids are composed of hematite. The nuclei of ooids are mainly quartz grains. Hematitic coatings are also around glauconitic peloids and quartz grains.

Ref.: Wanless, 1973.

320 – Abrigo ooidal ironstone

In outcrops in Ash Creek about 13 km east of Winkleman in southeast Arizona. In folded strata. An uneconomic deposit.

Age: Late Middle or early Late Cambrian. The ironstone is about 26 m below the top of the Abrigo Formation.

The ironstone is 1 m thick; ooids are hematitic.

Ref.: Elston and Bressler, 1977.

321 – Hickory ooidal ironstone

In the northwest part of the Llano Uplift, central Texas. In folded and faulted strata. Abandoned quarries.

Age: Early Late Cambrian. In the upper part of the Hickory Sandstone.

Major facies: A shallow marine shelf.

Ooids are composed mostly of hematite and goethite.

Chemical composition (%): Fe_2O_3 57.1–68.6, SiO_2 13.9–14.9, Al_2O_3 6.0–16.23, CaO 3.55–5.9, MgO 0.63–1.46, MnO 0.15–0.82.

Ref.: Barnes and Schofield, 1964.

322 – Reagan ooidal ironstones

In Limestone Hills in the Wichita Mountains, southwest Oklahoma. In folded and faulted strata. Uneconomic deposits.

Age: Late Cambrian. Three ironstones are within the clastic Reagan Formation which is above the Carlton Rhyolite and below the Honey Creek Formation of carbonate and clastic deposits.

Major facies: A marine nearshore to paralic setting.

The ironstones are as much as 5 to 20 m thick and are burrowed and cross-bedded.

The ooids and spastoliths are largely hematite and goethite, with minor chamosite? The nuclei are mainly broken fragments of fossils, peloids, and rare quartz grains.

Ref.: M. E. Purucker. Purucker, 1984.

323 – Mount Simon ooidal ironstone

In the central and north-central Iowa. In horizontal strata. An uneconomic deposit.

Age: Late Cambrian. In the Mount Simon Formation. Section is glauconitic.

Ref.: B. J. Witzke. Witzke, 1980.

324 – Bliss ooidal ironstones

In the Caballo, Pinos Altos, and San Andreas ranges, about 75 km south of Winston, southwest New Mexico. In folded strata. Uneconomic deposits.

Age: Late Cambrian. In the lower part of the Bliss Sandstone, overlain by the Early Ordovician limestone.

Major facies: A marine nearshore to shoreface setting.

The ironstones 0.3 to 2 m thick occur in 3 or 4 layers at the top of coarsening-upward sequences. Glauconitic peloids and phosphatic nodules are common in some ironstones.

The ooids are hematitic with some minor chamosite. The nuclei are mostly quartz or feldspar.

Chemical composition of the upper bed (%): Fe 23.2, SiO_2 43.9, CaO 3, P 0.51.

Ref.: D. Ottensman. Chafetz et al., 1986; Kelley, 1951.

Early Ordovician

325 – Ooidal ironstones

In outcrops just southwest of the bridge over Douglas Lake at Dandright, Jefferson County, about 45 km east of Knoxville, eastern Tennessee. In folded strata. Uneconomic deposits.

Age: Early Ordovician. In the uppermost Knox Group.

Major facies: A quiet marine setting.The ironstone lenses occur in the Fetzer facies.

Ooids are mainly chamosite, with goethite peloids.

Ref.: T. M. Chowns. Walker et al., 1992.

Middle Ordovician

326 – Oil Creek ooidal ironstone

In south-central Oklahoma. In a borehole. An uneconomic deposit.

Age: Early Middle Ordovician (Whiterockian). In the Oil Creek strata of the Lower Simpson Group.

Ref.: A. M. Foos.

327 – Ooidal ironstone

In the vicinity of an abandoned Deaton iron mine 2.2 km west of Taylorsville, Polk County, northwest Georgia. In folded strata.

Age: Middle Ordovician. In Lenoir Dolostone.

Major facies: A marine setting.

The ooids are chamosite, hematite, and magnetite.

Diagenetic effect: Chamosite was changed to hematite and magnetite.

Ref.: Chowns and McKinney, 1980.

328 – Ooidal ironstone of North Dakota

In north-central North Dakota. In boreholes. An uneconomic deposit.

Age: Middle Ordovician. In the Winnipeg Formation.

Major facies: A shallow marine shelf.

The ooids are hematitic.
Ref.: Witzke, 1980.

329 – Ooidal ironstone of South Dakota
In northwest South Dakota. In boreholes. An uneconomic deposit.
Age: Middle Ordovician.
In the Icebox Formation.
Major facies: A shallow marine shelf.
The ooids are hematitic.
Ref.: Witzke, 1980.

330 – Ooidal ironstones in central United States
In northeast Kansas, northeast and northwest Iowa, and southeast Minnesota. In level beds. In boreholes and outcrops. Uneconomic deposits.
Age: Late Middle Ordovician. In St. Peter Sandstone and overlying Glenwood, Plattesville, Decorah, and lower Galena formations.
Major facies: A shallow marine shelf.
The ironstones are seldom 2 to 4 m thick. The ooids are goethite or rarely hematite with minor siderite.
Ref.: P. Berendsen. Berendsen et al., 1992; Witzke, 1980.

Late Ordovician

331 – Ooidal ironstone (Virginia)
Along the James River in the southeast limb of Blue Ridge Anticline in the central Virginia Piedmont. In metamorphic folded and faulted strata. An uneconomic deposit.
Age: Late Ordovician. In the middle Arvonia Formation. The ironstone is 1.5 m thick. The ooids are composed of goethite and chamosite.
Ref.: Smith et al., 1964.

332 – Ooidal ironstones (Tennessee)
In outcrops along highway I-24 in Marion and Hamilton counties, in southeastern Tennessee. In folded strata. Uneconomic deposits.
Age: Late Ordovician. In the Shellmound Formation.
Major facies: A shallow sea.
The ironstone beds lie in calcareous siltstone and sandstone.
Ooids are mostly chamosite and hematite.
Ref.: T. M. Chowns. Wilson, 1979.

333 – Neda ooidal ironstone in Eastern Interior
In southeast Wisconsin, northeast Illinois, west-central Michigan, and northeast Indiana. In nearly horizontal strata. Abandoned mines in southeast Wisconsin; uneconomic deposits in other localities.
Age: Latest Ordovician (Ashgillian). In the upper Neda Member of the Maquoketa Formation, overlain by Early Silurian Mayville Dolomite.
Major facies: A shallow marine shelf.
The ironstone occurs in general in thin lenses, 0 to 11 m thick, in burrowed ferric-oxide mudstone. The ooids are ellipsoid or flattened and are mainly goethite, kaolinite, and calcite, and minor chamosite, phosphate, and quartz. The cores are mainly fossil fragments and quartz.
Average chemical composition (%): Fe_2O_3+FeO 79.5, MnO 3, SiO_2 6–10, Al_2O_3 2–5, CaO 0.5–6, MgO 0.14–6, P_2O_5 1–3.
Ref.: Hawley and Beavan, 1934; Kluessendorf, 1983; Mikulic and Kluessendorf, 1983.

334 – Neda and other ooidal ironstones in central United States
In southeast Nebraska, northeast Kansas, northwest and northeast Missouri, Iowa, and west-central Illinois. In horizontal strata. In boreholes. Uneconomic deposits.
Age: Latest Ordovician (Richmondian or Ashgillian). In the Neda, Brainard, Maquoketa, and Girardeau formations.
Ref.: B. J. Witzke. Witzke, 1980.

335 – Hooker ooidal ironstones
Near Hooker in the Lookout Valley in Dade County, northwesternmost Georgia and in Sequatchie Valley, Jackson County, northeasternmost Alabama. In folded strata. Abandoned mines.
Age: Latest Ordovician. In the mudstone of the Shellmound Formation.
Major facies: A shallow marine shelf.
The two ironstones in the lower part of the formation are ripple- and cross-bedded.
The ooids are chamosite and hematite in different proportions.
Ref.: T. M. Chowns. Chowns, 1972; Foos, 1983.

Early Silurian

336 – Ooidal ironstone (Tennessee)
In eastern Tennessee. In folded strata. Abandoned mines.
Age: Early Silurian. In the Rockwood Formation.
Major facies: A marine shelf.
The ooids are hematite, chamosite, siderite, and pyrite. Glauconitic limestone is present to the west.
Diagenetic effect: Chamosite was changged to hematite, siderite, and pyrite.
Ref.: Hudson and Maynard, 1986; Wilson, 1979.

Early and Middle Silurian

337 – Irondale and other ooidal ironstones
In the vicinity of Birmingham, northeast Alabama and in the northwest Georgia. In folded and faulted strata. Abandoned mines.
Age: Early (Llandoverian) and Middle? Silurian. Irondale and Greasy Cove ironstones are in the lower Red Mountain Formation, the Big Seam ironstone is in the middle, and the Ida and Hickory Nut ironstones in the upper formation. The Red Mountain formation is over the Late Ordovician Sequatchie Formation and below Devonian strata.
Major facies: A marine nearshore shelf.
These ironstones up to about 5 m thick are associated with cross-bedded sandstone.

The ooids consist of hematite and chamosite.

Average chemical composition (%): Fe 32–45, SiO_2 2–25, Al_2O_3 2–5, CaO 5–20, MgO 1–3, P_2O_5 0.28–1.5.

Ref.: T. M. Chowns. Burchard and Andrews, 1947; Chowns and McKinney, 1980; Simpson and Gray, 1968.

338 – Ooidal ironstones (New York)

From western New York near Buffalo, Niagara Gorge and the central-southernmost Ontario to central New York near Clinton. In essentially horizontal strata. Abandoned mines and quarries.

Age: Early and Middle Silurian. Two ironstones are in Early Silurian Grimsby and Cabot Head members in the west, seven ironstones are in the Early and Middle Silurian Clinton Group mainly in central New York.

Major facies: A marine shelf.

The ironstones are carbonate-rich facies to the west and mudstone and sandstone to the east. Ironstones range from a few cm to several m in thickness.

The ooids are largely hematite and goethite in the west, and hematite, goethite, and chamosite in the east.

Chemical composition (%): Fe_2O_3 30.2–51.8, SiO_2 8.71–11.84, Al_2O_3 0.48–3.67, CaO 7.34–20.6, MgO 3.76–7.84, MnO 0–tr., P_2O_5 0,49–0.75.

Ref. E. Cotter. Duke, 1987; Hunter, 1970; Schoen, 1964.

339 – Clinton and other ooidal ironstones

In southeastern Ohio, western Maryland, West Virginia, northern Virginia. In folded strata. Uneconomic deposits.

Age: Early and Middle Silurian. Early Late Silurian in the Williamsport area, west of Hagerstown, Maryland.

Ref.: Hunter, 1960; 1970; Meyer et al., 1987.

Early to Late Silurian

340 – Clinton ooidal ironstones (Pennsylvania)

In central and south-central Pennsylvania. In folded strata. Abandoned mines and uneconomic outcrops.

Age: Late Early to early Late Silurian. In the late Llandoverian Rose Hill, early Wenlockian Keefer, and late Wenlockian Mifflintown formations.

Major facies: A marine mid-shelf shoal and storm beds.

The ironstones are a few to several cm thick.

The ooids consist of hematite, goethite, chamosite, and berthierine.

Chemical composition (%): FeO 40.3–80.2, SiO_2 1.16–22.2, Al_2O_3 0.9–16.9, CaO 0.4–1.01, MgO 0.53–2.9, MnO 0–0.32, TiO_2 0.2–0.3.

Ref.: Cotter, 1993.

341 – Ooidal ironstone (Kentucky)

Near Olympia, Bath County, northeastern Kentucky. In folded strata. Abandoned mines.

Age: Silurian. At the top of the Brassfield Formation of limestone and a little claystone.

Major facies: A marine shelf.

The hematitic ooidal ironstone is about 0.5 m thick.

Ref.: McFarlan, 1943.

Middle Devonian

342 – Ooidal ironstones (Pennsylvania)

At Amity Hall, Girtys Notch, and Rockville in the New Bloomfield, Millersburg, and Harrisburg quadrangles in central Pennsylvania. In folded strata. In outcrops. Uneconomic deposits.

Age: Middle Devonian (Givetian). In the upper part of the Montebello Member (more than 200 m) of the Mahantango Formation.

Major facies: A shallow marine setting of an offshore delta.

The ironstones are thin lenses (0 to 10 cm) in dark gray silty mudstone at the top of the coarsening-upward sequence below. The ooids are formed around nuclei of quartz grains or broken ooids.

The ooids consist of hematite, goethite, chamosite, and berthierine, and collophane.

Ref.: A. R. Prave. Faill and Wells, 1974; Prave and Duke, 1990.

343 – Ooidal ironstone (Arizona)

In the area of Christmas north of Winkleman and south of Globe, Gila County, southeast Arizona. In folded strata. An uneconomic deposit.

Age: Middle Devonian. In the base of the upper shale part of the carbonate Martin Formation 400 m thick.

Major facies: A marine offshore setting.

The ironstone is 1 to 2 m thick. The ooids are enclosed in quartz silt and carbonate cement.

The ellipsoidal ooids consist of hematite and green clay.

The average chemical composition (%): Fe_2O_3 52.4, MnO 0.16, SiO_2 16.9, Al_2O_3 5.4, CaO 8.6, MgO 1.8, P_2O_5 1.7, TiO_2 0.23.

Ref.: Willden, 1960; 1961; 1964.

344 – Needmore ooidal ironstone

In an area near Clifton Forge in Alleghany County, western Virginia, and in western Maryland. Abandoned mines and outcrops. In folded strata.

Age: Middle Devonian.

Ref.: Inners, 1979; Lesure, 1957.

345 – Tully ooidal ironstones

In the area of Tully south of Syracuse in central New York. In horizontal strata. Uneconomic deposits.

Age: Late Middle Devonian. In the Tully strata.

Major facies: A marine nearshore shelf.

Ref.: Heckel, 1973.

Late Devonian

346 – Lock Haven and other ooidal ironstones

Near Mansfield in Tioga County, north-central Pennsylvania. Abandoned quarries. In nearly horizontal strata.

Age: Late Devonian. In Mansfield strata of mudstone and sandstone.

Major facies: A shallow sea.

Ref.: P. B. Luce. Luce, 1981.

347 – Ooidal ironstones in central United States

In northeast Kansas, Iowa, and northwest Missouri, southeast Nebraska.

Age: Late Devonian. In "Chattanooga", Maple Mill, or Saverton strata.

Ref.: P. Berendsen and B. J. Witzke. Carlson, 1963.

348 – Ooidal ironstone (New York)

In the Genesee Valley, southwestern New York. In horizontal strata. An uneconomic deposit.

Age: Late Devonian. In the Canadaway strata.

Ref.: Smyth, 1892; Williams, 1887.

Late Carboniferous

349 – Ooidal ironstones (Texas)

In subsurface just north of Amarillo Uplift in southwestern Anadarko Basin, Wheeler County, north-northwest Texas. Uneconomic deposits.

Age: Late Carboniferous (Pennsylvanian – Missourian).

Major facies: A marine sandy nearshore setting in front of a fan-delta system.

The ooids consist of chlorite. Most nuclei are quartz or feldspar grains but some nuclei are composed entirely of chlorite.

Diagenetic effect: May have produced authigenic chlorite rims soon after deposition.

Ref.: Dutton and Land, 1985.

Triassic

350 – Shublick ooidal ironstone

On the North Slope in the northernmost central Alaska. In outcrops and boreholes. In folded strata. An uneconomic deposit.

Age: Late? Triassic. In the Shublick Formation of mainly sandstone and mudstone.

Major facies: A marine offshore shelf.

The ironstone is several cm thick in mudstone and sandstone. The ooids are hematitic.

Ref.: J. T. Parrish. Parrish, 1987.

Early Cretaceous

351 – Ooidal ironstone

In the offshore New Jersey shelf in B-3 borehole. An uneconomic deposit.

Age: Early Cretaceous (Valanginian). Ironstone of about 4 m in coarsening-upward sandstone above mudstone.

Major facies: A shallow marine setting in a sand bar.

The ironstone with bioclasts lies in the upper part of the sandstone. Some of the ooids are spastoliths. Most of the ooids are green clay ("chamosite").

Ref.: Cunliffe, 1982.

Late Cretaceous

352 – Fite Ranch ooidal ironstone

Near Socorro in Socorro County, west-central New Mexico. In folded strata. An uneconomic deposit.

Age: Late Cretaceous (Turonian). In the Fite Ranch Sandstone Member 23 m thick, underlain by Mancos Shale or equivalent nonmarine Carthage Member of the Three Hermanos Formation and overlain by the Pescado Tongue of the Mancos Shale.

Major facies: A marine nearshore setting in a coastal-barrier bar.

The ooids are largely goethite.

Ref.: F. B. Van Houten. Hook et al., 1983.

353 – Floy ooidal ironstone

In the Book Cliffs at Floy 19 km east of Green River, Grand County, in east-central Utah. Another occurrence lies 32 km west of Green River in the Price River Canyon. In folded and faulted strata. An uneconomic deposit.

Age: Late Cretaceous (Santonian to Campanian). Correlated with the Emery Sandstone of the Blue Gate Shale Member of the Mancos Shale.

Major facies: A marine shallowing setting of a normal offshore shelf.

The ironstone 0.2 to 1.5 m thick is cross-bedded and is locally disrupted and contains burrows, fish teeth, and rip-up clasts.

The ooids are largely hematite and goethite and minor berthierine. The nuclei are mostly fine-grained quartz with minor feldspar and heavy mineral grains. The cement is carbonate.

Diagenetic effect: Berthierine was altered to hematite and goethite, and later carbonate cement was added.

Ref.: M. A. Chan. Chan, 1992.

354 – Ooidal ironstone (New Jersey)

At Tinton Falls about 5 km south of Red Bank in Monmouth County, east-central New Jersey. In horizontal strata. An uneconomic deposit.

Age: Latest Cretaceous (Maastrichtian). In Tinton Sand and underlying Red Bank Sand.

Major facies: A marine near-shore setting.

The ironstone with glauconite is abundant in the Tinton Sand and locally in the Lower Red Bank Sand.

The ooids apparently also contain some "glauconite".

Ref.: Owens and Sohl, 1973.

Paleogene

355 – Lone Star ooidal ironstone

Near Lone Star in northeast Texas. In horizontal strata. Minor active quarries.

Age: Paleogene (middle Eocene). In the Weches Formation.

Major facies: A marine near-shore setting.

The ironstone is mixed with glauconitic peloids. The unweathered ooids are composed mainly of berthierine, with matrix of kaolinite and berthierine and cement of siderite and pyrite. Weathered ironstone has gone to goethite.

Chemical composition (%): Fe_2O_3 69.92, MnO 0.09, SiO_2 9.44, Al_2O_3 6.63, MgO 0.30, TiO_2 0.19.

Ref.: A. M. Foos. Foos, 1984; 1987.

356 – Ooidal ironstone (Louisiana)

In Webster, Clairborne, Lincoln, and Bienville parishes, north-central Louisiana. In nearly horizontal strata. In outcrops and boreholes. An uneconomic deposit.

Age: Paleogene (middle Eocene). In four levels of about 50 m of the upper Cook Mountain and the lower Cockfield formations.

Major facies: A shallow marine deltaic setting.

The ironstones are in a burrowed clastic deposit.

The unweathered ooids and peloids are berthierine with siderite cement, and with berthierine in the matrix.

Weathered ironstones have gone to goethite and kaolinite.

Chemical composition (%):Fe_2O_3 19.22, FeO 11.44, MnO 0.39, SiO_2 35.56, Al_2O_3 13.92, CaO 1.20, MgO 1.20, TiO_2 0.45, P_2O_5 0.23.

Ref.: Jones, 1969.

Venezuela

Early Cretaceous

357 – Cogolla ooidal ironstone

In the Zulia Province in western Venezuela. In folded strata. An uneconomic deposit.

Age: Early Cretaceous (Aptian–Albian). In the Cogolla sequence.

Major facies: A marine setting.

The ironstone contains "chamosite" and glauconite.

Ref.: Sutton, 1946.

Late Cretaceous

358 – Colon ooidal ironstone

In the Merida Andes near Humocara Baja in the Lara State, in northwest Venezuela. In folded and faulted strata. An uneconomic deposit.

Age: Late Cretaceous (Maastrichtian). In the upper Colon Formation.

Ref.: Ulloa, 1978.

Paleogene

359 – Humocara ooidal ironstones

Humocara Baja in the southeast Falcon State, northwest Venezuela. In folded strata. Uneconomic deposits.

Age: Paleogene (early, middle, and late Paleocene). In the Humocara Formation.

Ref.: Ulloa, 1978.

360 – Arriba ooidal ironstone

In Quebrada Arriba near El Tocuyo and Humocara Baja in the southeast Falcon State, northwest Venezuela. In folded and faulted strata. Has future potential.

Age: Paleogene (early Eocene). In the middle part of the Quebrada Arriba Formation.

Major facies: A marine shoreline setting during regional transgression in a back-arc basin.The ironstone 3 to 8 m thick is underlain by limestone and overlain by sandstone. The ironstone is cross-bedded and burrowed, and associated with glauconite. The ooids consist of goethite, hematite, and berthierine, with minor green clay, calcite, siderite, and sulfide, and a clay matrix.

Average chemical composition (%): Fe_2O_3 59.3, SiO_2 21.5, Al_2O_3 8.7, P_2O_5 0.21.

Ref.: S. I. Rodriquez. Rodriquez, 1986.

361 – Misoa and Auji ooidal ironstones

In southeast Maracaibo Basin, northwest Venezuela. In folded strata. In boreholes. Uneconomic deposits.

Age: Paleogene (middle Eocene). In the lower part of the Misoa Formation, and in the overlying Pauji Formation.

Major facies: Marine shelf bars.

Ooids are goethite and berthierine.

Ref.: Ghosh and Di Croce, 1989.

Neogene

362 – Lagunillas ooidal ironstone

In northeast Maracaibo Basin, northwest Venezuela. In folded strata. In a borehole. An uneconomic deposit.

Age: Neogene (early or middle Miocene).

Major facies: A marine setting.

The ooids are goethite and a green clay.

Ref.: Kimberley, 1980.

Yugoslavia – Serbia

Early Jurassic

363 – Pesaca ooidal ironstones

In eastern Serbia 100 km south of Beograd, near Gornji Milankovac. In mixed siliciclastic-carbonate strata of a faulted and folded sequence. An uneconomic deposit.

Age: Early Jurassic (Pliensbachian). Rock below the ironstones is siltstone and above them is sandstone.

Major facies: Subtidal basin in regional transgression. Single thickness of ironstone is 10 to 60 cm. Composite thickness is at least 7 m.

Ooids are weathered and unweathered. Their composition is mainly chamosite, with minor goethite, hematite, calcite, siderite, and ankerite. Cement is quartz and calcium carbonate.

Simple ooids, to 1 mm, are very common. Bioclasts, to 3 cm, are abundant.

Diagenetic effect: Berthierine was changed to chamosite in early diagenesis.

Average chemical composition (%): FeO 40, MnO 0.01, SiO_2 26, Al_2O_3 19, CaO 0.55, MgO 4.

Ref.: J. Obradović. Vasić, 1990.

Early and Middle Jurassic

364 – Vidlitch ooidal ironstones

In easternmost Serbia near Zajetchar.

Age: Early Jurassic and Middle Jurassic (Callovian).

Major facies: Marine shoreline during transgression.

Single ironstone is from several cm to a few m thick. Composite ironstones are 5 to 20 m thick.

Ooids are 0.4 to 0.6 mm in diameter and mainly goethite, hematite, and siderite. The nucleus is quartz, calcite, and faunal fragments.

The average chemical composition: Fe 10–23 %.

Ref.: J. Obradović.

Early Cretaceous

365 – Shumadiya ooidal ironstone

In northern Serbia near Beograd and Kralyevo; 100 km extent through Beograd, Ralya, and Topola. In mixed siliciclastic-carbonate strata. An uneconomic deposit.

Age: Early Cretaceous – Aptian (Gault). Rocks below the ironstone are a siliciclastic-carbonate sequence.

Major facies: Marine shoreline in local progradation.

Partly redeposited lateritic material.

The ironstone is from 1 to 20 m thick.

Ooids, 0.5 to 0.8 mm in diameter, are abundant and are both weathered and unweathered. Multiple ooids, to 1 mm, are fairly rare. Pisoids, to 10 mm, are common.

Major ooids are goethite, hematite, and chamosite. Minor ooids are calcite and magnetite. Matrix is quartz and clay minerals.

Average chemical composition (%): Fe_2O_3 28–37, SiO_2 4–40, Al_2O_3 1–16, Cr_2O_3 0.5–1.2.

Near Beograd ironstone lies in sandy sediments and Fe content is 19–26. At Ralya the ironstone lies in sandy sediments and Fe content is 35–40 with chamosite ooids (54 %), hematite ooids (23 %), and goethite ooids (16 %). At Topola the ironstone lies in sandy sediments and Fe content is 25–35, with hematite and goethite ooids.. At Gledice Mountain the ironstone lies in limestone in sandy sediments and Fe content is 30–37 with mainly chamosite ooids.

Ref.: J. Obradović. Janković, 1977/1978.

366 – Mokra Gora ooidal ironstone

In southern Serbia 20 km west of Uzhitse which is 175 km south-southwest of Beograd. In siliciclastic sequence. An uneconomic deposit.

Age: At the base of the Late Cretaceous.

Partly redeposited lateritic material. Ironstone lies above serpentinite and Paleozoic schist and below Late Cretaceous strata of sandstone and marlstone.

Major facies: Marine shoreline during transgression.

The ironstone is as much as 10 to 30 m thick. It contains pisoids as well as ooids.

Ooids are variously composed of hematite, goethite, maghemite, and pyrite. Matrix is mostly quartz and clay minerals.

Chemical composition (%): Fe 20–41, Cr 1.1–1.7.

Ref.: J. Obradović. Janković, 1977/1978.