Depósitos e Potencial Nacional para Manganês

Deposits and National Potential for Manganese

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Prof. Titular da Universidade Federal do Pará
Pesquisador do CNPQ

Ouro Preto (MG). 16 de maio de 2016
Auditório São João Del Rei. 11:05 – 11:30h
OUTLINE

• Importance of Manganese in the Mineral Industry
• World Manganese Market
• Brazilian Manganese Resources
• Manganese Researches and Geological Settings
• Brazilian Manganese Deposits and Occurrences
• Conclusions
MANGANESE AND IRON ON PERIODIC TABLE

Continental Crust Contents: Fe 6.28% and Mn 0.10%
What is steel made from? Many people would correctly respond that steel is made of iron. Far fewer know that it is also made of manganese, in small amount of manganese. It is just essential for modern industrial societies. Put in simplest terms—you can’t make steel without manganese.
PRE-HISTORIC APPLICATION

Ancient Egyptians and Romans used pyrolusite, MnO₂, to control the color of glass. Small additions decolorized glass by removing the greenish yellow discoloration caused by iron impurities. It is still used today as a colorant. Photo by Scott Jackson. USGS.
Did you know...

In Ancient Greece, the natural presence of manganese in the iron ore used by the Spartans may explain why their steel weapons were superior to those of their enemies.

USGS Mineral Resources Program
MANGANESE APPLICATIONS

• Manganese removes oxygen and sulfur when iron ore is converted into iron.
• It helps convert iron into steel.
• The amount of manganese: rather small: 6 to 9 kg/ton Steel.
• Manganese is used also as an alloy with Al and Cu.
• Nonmetallurgical uses: battery cathodes, soft ferrites, micronutrients and animal feed, water treatment chemicals, and other chemicals (automobile undercoat paints, bricks, frits, glass, textiles, and tiles); Electrolytic products.
• The “manganese violet” is used for the coloration of plastics, powder coatings, artist glazes, and cosmetics.
Electrolytic Manganese Products

Electrolytic Manganese Metal Flakes
USD2000 - 2050 / Ton

Manganese Tetroxide Mn3O4
USD1900 - 2000 / Ton

Electrolytic Manganese Metal Powder
USD2250 - 2350 / Ton

Manganese Metal Briquettes
USD2100 - 2150 / Ton

http://www.electrolyticmanganese.com/, 15.5.16, Hunan Co., Ltd.
U.S. DEMAND FOR MANGANESE

• All manganese ore consumed in the United States is imported. From 2008 to 2011: Gabon (61 %), Australia (21 %), South Africa (7 %) and Brazil (5 %).

• Ferromanganese imports, 2008 to 2011: South Africa (51 %), China (13 %), Ukraine (8 %), and the Republic of Korea (7 %).

• Silicomanganese: from South Africa (41 %). Georgia (23 %). Norway (14 %). and Australia (11 %).

• Demand for manganese historically closely follows steel production and is expected to do so in the future: 1 to 2 % (per year) for USA.
**MANGANESE WORLD MINE PRODUCTION AND RESERVES (METAL CONTENT)**

**World Mine Production and Reserves (metal content):** Reserves for India have been revised based on the average metal content of manganese ore produced from 2009–13.

<table>
<thead>
<tr>
<th></th>
<th>Mine production</th>
<th></th>
<th>Reserves&lt;sup&gt;14&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2013</td>
<td>2014&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Australia</td>
<td>2,980</td>
<td>3,100</td>
<td>3</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,120</td>
<td>1,100</td>
<td>5</td>
</tr>
<tr>
<td>Burma</td>
<td>157</td>
<td>200</td>
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</tr>
<tr>
<td>China</td>
<td>3,000</td>
<td>3,200</td>
<td>2</td>
</tr>
<tr>
<td>Gabon</td>
<td>1,970</td>
<td>2,000</td>
<td>4</td>
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<tr>
<td>Ghana</td>
<td>533</td>
<td>540</td>
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<tr>
<td>India</td>
<td>920</td>
<td>940</td>
<td>5</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>390</td>
<td>390</td>
<td>5,000</td>
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<tr>
<td>Malaysia</td>
<td>430</td>
<td>440</td>
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<tr>
<td>Mexico</td>
<td>212</td>
<td>220</td>
<td>5,000</td>
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<tr>
<td>South Africa</td>
<td>4,300</td>
<td>4,700</td>
<td>1</td>
</tr>
<tr>
<td>Ukraine</td>
<td>300</td>
<td>300</td>
<td>140,000</td>
</tr>
<tr>
<td>Other countries</td>
<td>597</td>
<td>650</td>
<td>Small</td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>16,900</td>
<td>18,000</td>
<td>570,000</td>
</tr>
</tbody>
</table>

**World Resources:** Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 75% of the world’s identified manganese resources, and Ukraine accounts for 10%.

**Substitutes:** Manganese has no satisfactory substitute in its major applications.
Global Manganese Production

Production in Thousand Metric Tons by Country

- South Africa: 3,800 (2012), 3,100 (2013)
- Australia: 3,100 (2012), 2,000 (2013)
- China: 3,100 (2012), 2,000 (2013)
- Gabon: 1,400 (2013)
- Brazil: 850 (2012), 1,400 (2013)
- Mexico: 950 (2013)
- Burma: 950 (2013)
- Other Countries: 250 (2012), 950 (2013)

Total Manganese Production in 2012: 15,808,000 metric tons
Total Manganese Production in 2013: 16,510,000 metric tons


https://www.proactiveinvestors.co.uk/upload/SponsorFile/File/400_2015_10/cancana_presentation.pdf
Average Grade of Major Manganese Ore-Producing Countries in 2014

Mamatwan manganese mine in the Kalahari District of South Africa. A thick layer of manganese ore is mined from this open pit mine. The mine benches follow the sedimentary layering of the ore body. Photo by William Cannon. USGS
EVOLUTION OF MANGANESE PRICES
US$/TON. FOB: 2001 - 2010

2015:
3.03 DMTU x 54% Mn = $163 per ton FOB
BMC selling at +30% premium = ~$211 per ton
(mine gate)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Unit</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>% World 2013</th>
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<tr>
<td>Iron</td>
<td>(t)</td>
<td>398,130,813</td>
<td>400,822,000</td>
<td>386,270,053</td>
<td>13.1</td>
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<tr>
<td>Aluminum-bauxite</td>
<td>(t)</td>
<td>31.768.000</td>
<td>33.260.000</td>
<td>32.867.000</td>
<td>12.7</td>
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<tr>
<td><strong>Manganese</strong></td>
<td>(t)</td>
<td><strong>2.738.000</strong></td>
<td><strong>2.796.000</strong></td>
<td><strong>2.833.000</strong></td>
<td><strong>7.2</strong></td>
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<tr>
<td>Kaolin</td>
<td>(t)</td>
<td>1.927.000</td>
<td>2.388.000</td>
<td>2.139.000</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Brazil manganese reserves are of 235 million tons of ore contained. The State of Minas Gerais is where there are the largest reserves with 87% of the total, followed by Mato Grosso do Sul with 6.5%. Pará with 4.3% and other states with 2.2%

INTERNATIONAL RESEARCH PROGRAMS PUBLISHED ON Mn
(Ore Geology Reviews, 2012):

• Geology and Geochemistry of Manganese I. II. III (IGCP 111; Varentsov and Grasselly. eds.. 1980); Manganese Deposits (IGCP 111; Roy. 1981);
• Manganese Metallogenesis (IGCP 226; Bolton ed.. as Special Issues of Ore Geology Reviews. 1988. 1990. 2012);
• Special Issue on Manganese Metallogenesis (IGCP 226; Bolton ed.. as Special Issue of Economic Geology. 1992);
• Precambrian to modern manganese mineralizations: changes in ore type and depositional environment (IGCP 318; Nicholson et al.. eds.. 1997);
• Manganese and associated ore deposits of China (IGCP 226 and 318; Hein and Fan. eds.. as Special Issue of Ore Geology Reviews. 1999); and Manganese Ores of Hungary (IGCP 111. 226. 254. 318. 357. 429; Polgári et al.. eds.. 2000).
• Despite this success, no international collaboration program has come into existence to support research into the origin of manganese deposits since the end of IGCP 429 in 2002.
<table>
<thead>
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<th>AGE</th>
<th>DEPOSITS, SEQUENCES COUNTRIES</th>
<th>GEOLOGICAL SETTINGS</th>
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<tr>
<td><strong>ARCHEAN</strong></td>
<td></td>
<td></td>
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<tr>
<td>2.6 A 2.9</td>
<td>India. Nova Lima. Jequie</td>
<td>Shallow-shelf interbedded Mn oxides, chert, phyllite, greywacke, stromatolites, Mn</td>
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<tr>
<td></td>
<td><strong>BURITIRAMA, CAETITÉ</strong></td>
<td>silicate-carbonate, black shales</td>
</tr>
<tr>
<td><strong>PALEOPROTEROZOIC</strong></td>
<td></td>
<td></td>
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<tr>
<td>2.0 A 2.5</td>
<td>Birimian (WAf). Minas SG (M.G).</td>
<td>Shallow-shelf Mn oxides carbonate pelites; Shelf carbonate, orthoquartzite,</td>
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<tr>
<td></td>
<td>Hotazel FM (SA). Rooinekke FM</td>
<td>pelite, Mn oxides silicate±carbonate; Intracratonic rift-related greenstone belt,</td>
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<tr>
<td></td>
<td>Transvaal SG. Chitraduarga G (IN)</td>
<td></td>
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<tr>
<td></td>
<td><strong>AZUL; Morro da Mina, S Navio</strong></td>
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<td><strong>NEOPROTEROZOIC</strong></td>
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<td>625 A 800 MA</td>
<td><strong>Jacadigo</strong> G (BR. BO). China.</td>
<td>Glaciomarine Seq.: Mn oxide, BIF, dropstone,. Clastics, black shales Mn-</td>
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<td></td>
<td>Damara S. (Namibia)</td>
<td>carbonate.</td>
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<td>Penganga G. (IN)</td>
<td>Shelf sequences (no glaciation).</td>
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<td><strong>PALEOZOIC-MESOZOIC</strong></td>
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<tr>
<td></td>
<td>Turkey</td>
<td>Carbonate-black shales Mn carbonate and oxides; oolitic Mn oxides siltstones; Mn</td>
</tr>
<tr>
<td></td>
<td>Australia</td>
<td>carbonate and black shales</td>
</tr>
<tr>
<td></td>
<td>Mexico, Hungary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kazakhstan</td>
<td></td>
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<tr>
<td><strong>OLIGOCENE</strong></td>
<td>Nikopol, Chiautra (Ukraine,</td>
<td>Shallow-shelf, Mn carbonate, oxides rel. to siltstones, claystones, dolomites</td>
</tr>
<tr>
<td></td>
<td>Georgia)</td>
<td></td>
</tr>
</tbody>
</table>
Schematic representation of Mn deposition related to sea level changes

A

Stratified Ocean

Input of reducing gases by volcanic/ hydrothermal activity

2+ 4+ Mn/Mn Redoxcline

Oxic

Anoxic

Organic-rich detritus run-off
Primary productivity by nutrient upwelling

Mn oxide deposition on shelf

2+ 4+ Mn/Mn Redoxcline

Oxic

Anoxic

Mn oxyhydroxide particulates

Mn²⁺ advection

sinking of organic particulates

B

Marine Transgression

C

Ocean Anoxia

Burial of Mn oxyhydroxide and Mn carbonate formation

Primary productivity

Mn oxyhydroxide particulates

Anoxic sediments enriched in degrading organic matter producing C_{org} and HCO₃⁻
SCHEMATIC REPRESENTATION SHOWING THE INTERRELATIONSHIP AMONG TECTONISM, CLIMATIC CHANGES AND MN DEPOSITION. ROY (2006)

Mantle Upwelling, elevation of supercontinents to a domed geoid high

Expansion of continental freeboard, intense silicate weathering

Substantial drawdown of atmospheric CO₂

Glaciations and fall of sea level

Highly saline, Fe, Mn rich but O₂ deficient seawater beneath the ice cover

Break up of supercontinents

Marine transgression

Volcanism, hydrothermal activity and massive release of greenhouse gases

Advection of dissolved Mn^{2+} ± Fe^{2+} from anoxic deep water to oxic upper zone and deposition of Mn ± Fe oxyhydroxide on subsided new continental shelves

Cap carbonates (−δ^{13}C) of glaciogenic sequences formed by high ¹²C from mantle and/or release of CH₄ from gas hydrate destabilization

(Top) Classification of Mn oxide deposits based on Mn–Fe–(Cu+Co+Ni10) from Baby Bare seamount as (A) diagenetic. (B) hydrogenous (Hein et al., 1992b). or (C) hydrothermal. The diagenetic and hydrothermal fields are after Bonatti et al. (1972). (Bottom) Classification of Mn oxide deposits based on Mn–Fe–Si2 (Toth, 1980) as (A) diagenetic. (B) hydrogenous. or (C) hydrothermal for samples from Baby Bare seamount. C.E. Fitzgerald. K.M. Gillis.

Hydrothermal manganese oxide deposits from Baby Bare ...
MANGANESE IN BRAZIL

- Azul, Carajás (PA)
- Buritirama, Carajás (PA)
- Urucum, Corumbá (MS)
- Morro da Mina, C. Lafaiete (MG)
- Sereno, Carajás (PA)
- Buriti, Carajás (PA)
- Cumaru do Norte (PA)
- Caetité (BA)
- Serra do Navio (AP)
- Apuí (AM)
- Aurizona (MA)
- Cancana (RO)
- Dom Silvério (MG)
- S. Joao da Aliança (GO)
- Morro dos Melos (PI)
- Cristalândia (PI)
- Ipitinga (PA)
- Juína (MT)
- Santana (PA)
MANGANESE: MINES, DEPOSITS AND OCCURRENCES IN BRAZIL

Main and Selected Mineral Provinces and Districts

1. Serra Lombarda/Tartarugalzinho (Au)
2. Vila Nova (Au, Cr)
3. Parima (Au, Sn)
4. Carajás (Fe, Mn, Au, Cu, Ni)
5. Tapajós (Au)
6. Alta Floresta/Aripuanã (Au, Zn, Pb, Cu)
7. Rondônia (Sn, Au)
8. Alto Guaporé (Au)
9. Alto Jaraú (Au, Cu)
10. Cuiabá/Pocóné (Au)
11. Alto Araguaí (diamante)
12. Coxim (diamante)
13. Salto do Jacuí (ágata, ametista)
14. Alto Uruguaí/Irai (ágata, ametista)
15. Vale do Ribeira (Pb, Zn, Ba, Ag)
16. Alto Paranaíba (diamante)
17. Morro Agudo/Vazante (Zn, Pb)
18. Quadrilátero Ferrífero (Fe, Mn, Au)
19. Brasil Ocidental (Li, Be, gemas)
20. Diamantina (diamante)
21. Chapada Diamantina (diamante)
22. Riu Itapicuru (Au)
23. Rio Jacurici/Campo Formoso (Cr)
24. Rio Curuçá (Cu)
25. Seridó/Borborema (W, Nb)

Principal mineral provinces and districts Source: Brazilian Geological Service (CPRM)
MANGANESE DEPOSITS IN THE CARAJÁS DOMAIN

BURITIRAMA
BURITI
CONQUISTA
SERENO
AZUL
S. NORTE
S. SUL
AZUL MANGANESE DEPOSIT, CARAJÁS (PARÁ)
AZUL MANGANESE DEPOSIT. CARAJÁS: SEDIMENTARY, HYDROTHERMAL, LATERITIC AND COLLUVIONAR AND PALEOCHANEL
Conquista (Sereno) Manganese Deposit, Carajás (hydrothermal/Shear zone)
BURITI MANGANESE DEPOSIT, CARAJÁS (PA): sedimentary stratification
GEOLOGICAL EVOLUTION OF AZUL MANGANESE DEPOSIT

Sedimentation
SEDIMENTAÇÃO + DEFORMAÇÃO
1. SEDIMENTAÇÃO E DIAGÊNESE
   PALEOPROTEROZÓICO
   OH-Mn
   Mn(Rd)
   Fonte de Mn ↔ Rodocrosita, OH-Mn, clorita, illita, esmecitita, pirita e calcopirita.

Tectonic
DEFORMAÇÃO: CAULINIZAÇÃO E PIRITIZAÇÃO VENULAR PROTEROZÓICO
2. DEFORMAÇÃO: CAULINIZAÇÃO E PIRITIZAÇÃO VENULAR PROTEROZÓICO
   OH-Mn
   OH-Mn
   Mn(Rd)
   Remobilização e neoformação de Mn ↔ Carbonato, OH-Mn e clorita. Venulações e bolsões de caulim, de pirita e calcopirita.

Lateritization
LATERITISAÇÃO
3. LATERITIZAÇÃO MURATA (TERCIÁRIO INFERIOR)
   64 a 68 Ma.
   OH-Mn
   Mn(Rd)
   ARGILOSO
   ARGILÓSICO
   Decomposição de: rodocrosita, clorita, illita, esmectita, feldspatos e pirita. Formação de: OH-Mn, OH-Fe, gibbsita, caulinita e anatásio.

Erosion, Paleochanel
4. DESMANTELAMENTO: LATOSÓLLOS COM ESFEROLITOS E COLÚVIOS.
   24 a 26 Ma.
   M. Argiloso com esferolitos
   OH-Mn
   OxhMn
   Formação de: esferolitos de OH-Mn (litioforita) com caulinita, gibbsita e goethita.
Buritirama is formed by micaceous quartzites, overlapped by mica schists hosting manganese ore lenses, ferruginous banded quartzite and thick unit of mica schist and quartz schists. The manganese ore is restricted to altered mica schists, intercalated with quartzite. Manganese ore minerals: cryptomelane, lithiophorite and \( (\text{MnO}_2) \) amorphous Mn.
SERRA DO NAVIO, AMAPÁ

Intra-arc sedimentation, metamorphic, hydrothermal, lateritic
SERRA DO NAVIO LATERITIC PROFILE
Mn ore deposit
Mineral chemistry of garnets from three representative samples at Serra do Navio*

* B.C. Chisonga et al. / Ore Geology Reviews 47 (2012) 59–76
CAETITÉ (BA): metamorphic (archean volcanosed: Licínio de Almeida-Caetité Comp., hydrothermal, lateritic)
MORRO DOS MELOS PI, Hydrothermal
CANCANA MANGANESE DEPOSITS (RO), tectonic-related hydrothermal

MORRO DA MINA, CONSELHEIRO LAFAIETE (MG), VALE (2006): metasedimentary

Comprimento: 870 m
Largura: 400 m
Profundidade: 130 m
Altura da Bancada: 10 m

http://www.maxwell.vrac.puc-rio.br/12068/12068_4.PDF ACESSADO 06.5.16

<table>
<thead>
<tr>
<th>Era</th>
<th>Supergroup</th>
<th>Group</th>
<th>Formation</th>
<th>Lithotypes</th>
<th>Age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleoproterozoic</td>
<td>Minas</td>
<td>Sabara</td>
<td></td>
<td>Phyllite, quartzite, graywacke, conglomerate</td>
<td>U–Pb zircon 2125 ± 4</td>
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<tr>
<td></td>
<td></td>
<td>Piracicaba</td>
<td></td>
<td>Orthoquartzite, phyllite, dolomite, conglomerate</td>
<td>Pb–Pb carbonate 2480 ± 19</td>
</tr>
<tr>
<td></td>
<td>Itabira</td>
<td></td>
<td>Local erosional unconformity: Gandarela</td>
<td>Stromatolitic limestone, dolomite, BIF (itabirite) with Mn oxide beds and lenses</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Merging boundary-</td>
<td>Caué: BIF (itabirite), minor dolomite, phyllite</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Batatal: Phyllite, chert, black shale, BIF</td>
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</tr>
<tr>
<td></td>
<td>Carasa</td>
<td></td>
<td></td>
<td>Moeda: Conglomerate, pelites, psammites</td>
<td>U–Pb ca. 2580</td>
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--- Erosional and angular unconformity ---

<table>
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<tr>
<th>Archean</th>
<th>Marquíné</th>
<th>Casa Forte</th>
<th>Quartzite, phyllite, conglomerate</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Palmital</td>
<td></td>
<td>Phyllite, quartzite, graywacke, conglomerate</td>
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--- Erosional and Angular Unconformity ---

<table>
<thead>
<tr>
<th>Archean</th>
<th>Rio das Velhas</th>
<th>Clastic unit</th>
<th>Graywacke, carbonate, conglomerate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nova Lima</td>
<td>Pyroclastic unit</td>
<td>Tuffs, agglomerates</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Metasedimentary chemical unit</td>
<td>Carbonate, black shale hosted Mn silicate–carbonate protore, carbonate–facies BIF, conglomerate–chert Pillowed and massive basalts, cherts, BIF</td>
<td>U–Pb age 2780–2772</td>
</tr>
</tbody>
</table>

Basement of granite gneiss and granitoids: U–Pb ca. 2970
Fe–Mn Corumbá: sedimentary

GEOLOGICAL MAP AND CROSS SECTION OF THE CORUMBÁ GRABEN SYSTEM

T. Angerer et al. / Precambrian Research 275 (2016) 369–393

625 Ma
CONCLUSIONS

- Manganese is an important mineral commodity and Brazil is a minor player
- Supergenic (Lateritic weathering) deposits are already discovered and exhausted;
- The supergenic deposits were overestimated and excluded attention on primary ore;
- Archean and Proterozoic Terrains play a great role in geology of Brazil;
- Little has been done in mineral exploration for Mn in the Archean and Proterozoic Terrains; Carajás needs to be considered: BIF
- Small and high grade deposits (hydrothermal, supergenic and sedimentary) for micronutrients, electrolytic, etc., show high potential.
Thanks!

Obrigado!
Participation and position in the world ranking of major mineral reserves. DNPM - Sumário Mineral 2014.
## IRON AND STEEL (Fe and Mn)

<table>
<thead>
<tr>
<th>World Production:</th>
<th>Pig iron</th>
<th>Raw steel</th>
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<tbody>
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<td>2013</td>
<td>2014&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>United States</td>
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<tr>
<td>United Kingdom</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Other countries</td>
<td>113</td>
<td>119</td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>1,180</td>
<td>1,190</td>
</tr>
</tbody>
</table>

USGS. SMC. 2015
# U.S. MANGANESE INDUSTRY

## Salient Statistics—United States

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production, mine</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Imports for consumption:</strong></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Manganese ore</td>
<td>489</td>
<td>552</td>
<td>506</td>
<td>549</td>
<td>430</td>
</tr>
<tr>
<td>Ferromanganese</td>
<td>326</td>
<td>348</td>
<td>401</td>
<td>331</td>
<td>360</td>
</tr>
<tr>
<td>Siliconmanganese</td>
<td>297</td>
<td>348</td>
<td>348</td>
<td>329</td>
<td>450</td>
</tr>
<tr>
<td><strong>Exports:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Manganese ore</td>
<td>14</td>
<td>1</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Ferromanganese</td>
<td>19</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>7</td>
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<tr>
<td>Siliconmanganese</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>2</td>
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<tr>
<td><strong>Shipments from Government stockpile excesses:</strong></td>
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<tr>
<td>Manganese ore</td>
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<td>-75</td>
<td></td>
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<tr>
<td>Ferromanganese</td>
<td>29</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td><strong>Consumption, reported:</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Manganese ore</td>
<td>450</td>
<td>532</td>
<td>538</td>
<td>523</td>
<td>500</td>
</tr>
<tr>
<td>Ferromanganese</td>
<td>292</td>
<td>303</td>
<td>382</td>
<td>368</td>
<td>370</td>
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<tr>
<td>Siliconmanganese</td>
<td>97</td>
<td>106</td>
<td>150</td>
<td>152</td>
<td>150</td>
</tr>
<tr>
<td><strong>Consumption, apparent, manganese</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>721</td>
<td>699</td>
<td>843</td>
<td>794</td>
<td>840</td>
</tr>
</tbody>
</table>

Price, average, 46% to 48% Mn metallurgical ore, dollars per metric ton unit, contained Mn:
- Cost, insurance, and freight (c.i.f.), U.S. ports:
  - CNF, China, CRU Ryan’s Notes

Stocks, producer and consumer, yearend:
- Manganese ore
- Ferromanganese
- Siliconmanganese

Net import reliance as a percentage of apparent consumption:
- 100

**Recycling:** Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.
BRAZILIAN EXPORT AND IMPORT FOR MINERAL COMMODITIES - 2014

Exportações 2014

Ferro 75%
Manganês 1%
Alumínio 1%
Pedras Nat. e Revest. 1%
Cobre 5%
Ornamentais 4%
Ferronióbio 5%
Ouro 7%
Outros 2%

Importações 2014

Potássio 37%
Carvão 35%
Outros 7%
Zinco 2%
Enxofre 4%
Pedras Nat. e Revest. Ornamentais 1%
Rocha Fosfática 2%

IBRAM. 2015.
## MANGANESE RESEARCH
### IGCP PROGRAMS WITH IMPORTANT IMPACT

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Duration</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>111</td>
<td>1975–1985</td>
<td>Genesis of manganese ore deposits</td>
</tr>
<tr>
<td>226</td>
<td>1986–1990</td>
<td>Correlation of manganese sedimentation to paleoenvironments</td>
</tr>
<tr>
<td>357</td>
<td>1993–1997</td>
<td>Organics and mineral deposits</td>
</tr>
<tr>
<td>429</td>
<td>1998–2002</td>
<td>Organics in major environmental issues</td>
</tr>
</tbody>
</table>

Source: Preface - Manganese metallogenesis
Introduction to the special issue Ore Geology Reviews 47 (2012) 1–4
SOME GEOLOGICAL SETTINGS

- Exhalative seafloor, Archean, Fe-Mn;

- *Shallow shelf or intra-arc basins*, Archean-Paleoproterozoic: Mn (oxides, carbonates, sulphides);
  - Metamorphic (gondites, queluzites): CL, DS, SN; AU, BR, CA
  - No-Metamorphic: AZ, AP.

- Deposited during active (half-) graben tectonics probably in a continental failed rift back-arc (Jacadigo Group**); Jacadigo iron and manganese deposits formed in estuaries or coastal ***

- Hydrothermals

- Oceans rather than in rivers or lakes.

- Lateritic weathering

- Exhalative Modern Seafloor: Mn-Co-Ni

Fe–Mn CORUMBÁ: sedimentary
Chondrite-normalized rare earth element plot for Mn-oxide crusts from Baby Bare