7. Marktplatz Zulieferer
Wasserstoff- und Brennstoffzellentechnologie
31. August 2022

Rohstoffe für Wasserstofftechnologien – Fokus Platingruppenelemente –

Michael Schmidt
Deutsche Rohstoffagentur (DERA)
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Federal Ministry
for Economic Affairs
and Climate Action

The Federal Institute for Geosciences and Natural Resources is the central geoscientific authority providing advice to the German Federal Government in all geo-relevant questions. It is subordinate to the Federal Ministry for Economic Affairs and Climate Action (BMWK).

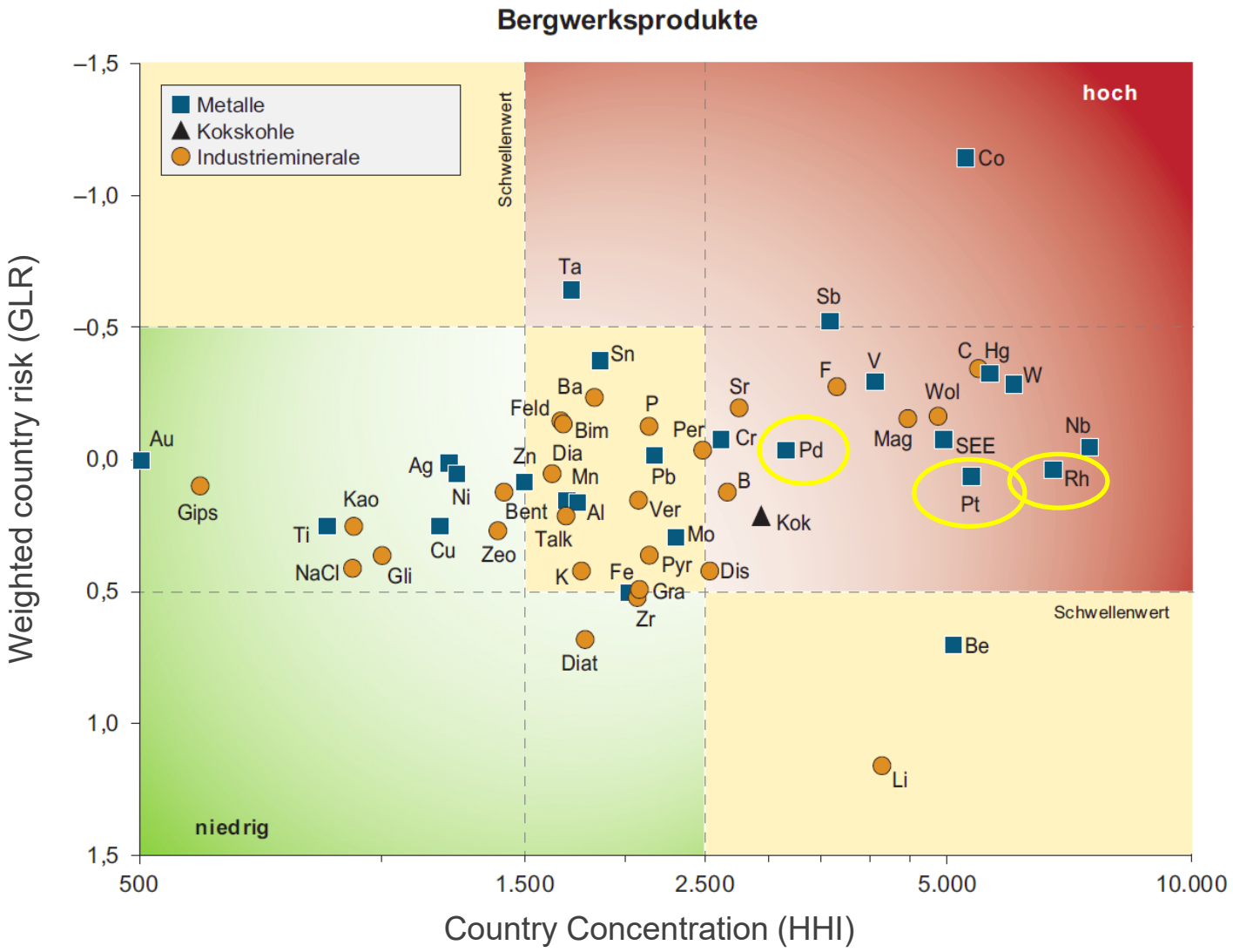
German Mineral Resources Agency (DERA) at BGR

- Federal Institute for Geosciences and Natural Resources (BGR):
  Central authority providing advice to the German Government in all geo-relevant questions.
- Subordinate to the Federal Ministry for Economic Affairs and Climate Action (BMWK).

https://www.deutsche-rohstoffagentur.de/DERA/DE/Home/dra_node.html
https://www.bgr.bund.de/DE/Home/homepage_node.html

https://www.bmwi.de/Redaktion/DE/Artikel/Industrie/rohstoffstrategie-bundesregierung.html

DERA Raw Materials List 2021

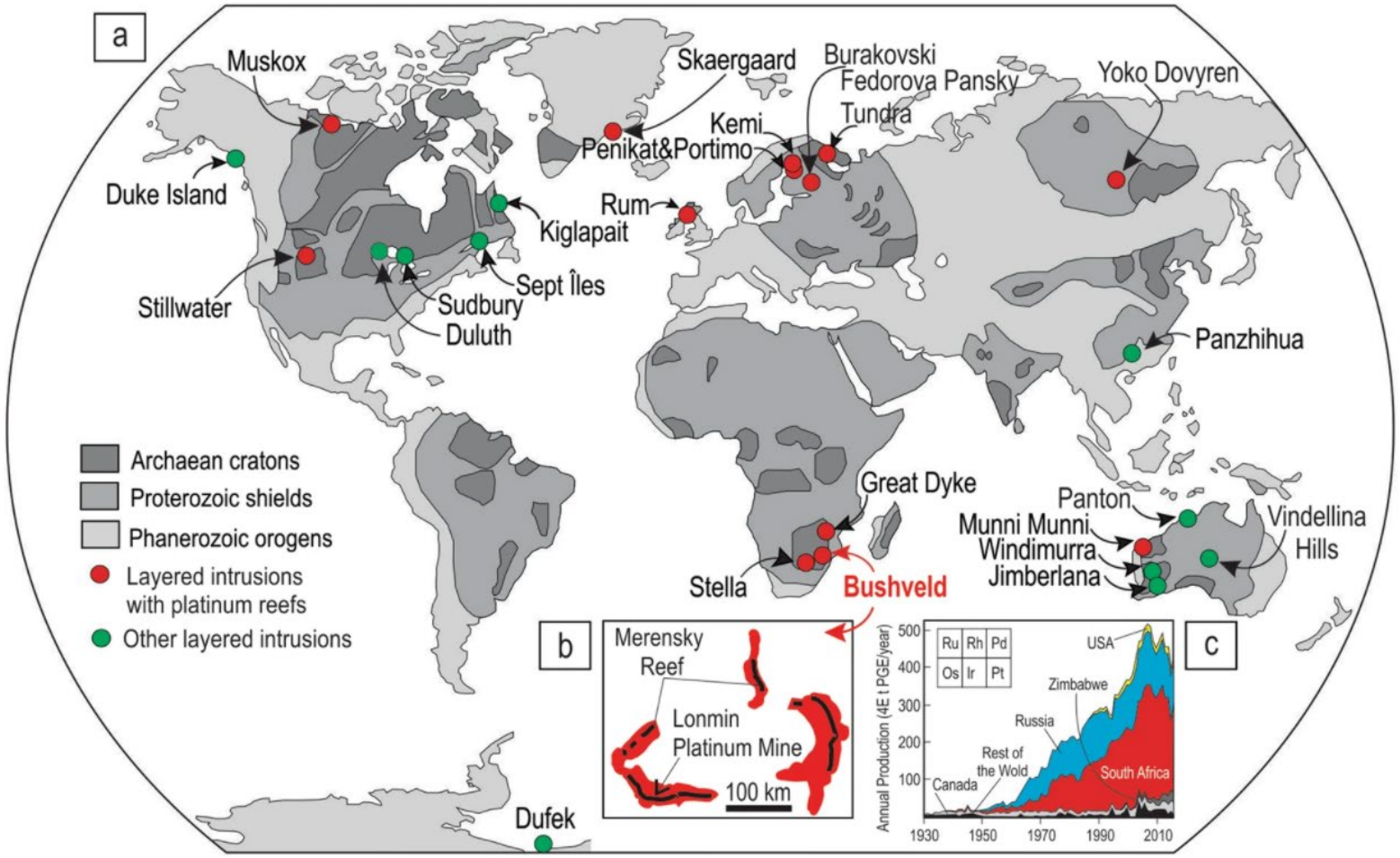


49 DERA Rohstoffinformationen

DERA-Rohstoffliste 2021

Angebotskonzentration bei mineralischen Rohstoffen
und Zwischenprodukten – potenzielle Preis- und Lieferrisiken

Occurences of PGMs



UG-1 Upper Critical Zone at Dwars River Heritage Site. (Schmidt 2013)

Source: https://www.nature.com/articles/s41598-019-45288-8

PGM Dominated Deposits

Tab. 3: PGM-dominierte Lagerstätten (Datenquelle: Gunn 2014).

Lagerstättentyp	Gehalte Ø [g/t]	Lagerstätten
Merensky	5 – 7 (Pt + Pd)	Merensky Reef (Bushveld-Komplex, Rep. Südafrika), Great Dyke (Simbabwe), J-M Reef (Stillwater-Komplex, USA)
Chromitite	4 – 8 (Pt + Pd), 0,3 – 0,6 (Rh) [UG2]	UG2 (Bushveld-Komplex, Rep. Südafrika), Lower Chromitites (Stillwater-Komplex, USA)
Kontakttyp	1 – 4 (Pt + Pd) [Platreef]	Platreef (Bushveld-Komplex, Rep. Südafrika), Duluth-Komplex (USA), East Bull Lake (Kanada), Portimo (Finnland)
Dunite Pipes	3 – 2.000 (Pt + Pd) (ausgeerzt)	Onverwacht, Driekop, Mooihoek (Bushveld-Komplex, Rep. Südafrika)

Tab. 4: Durchschnittliche PGM-Gehalte im Bushveld-Komplex (Datenquelle: Jones 2005).

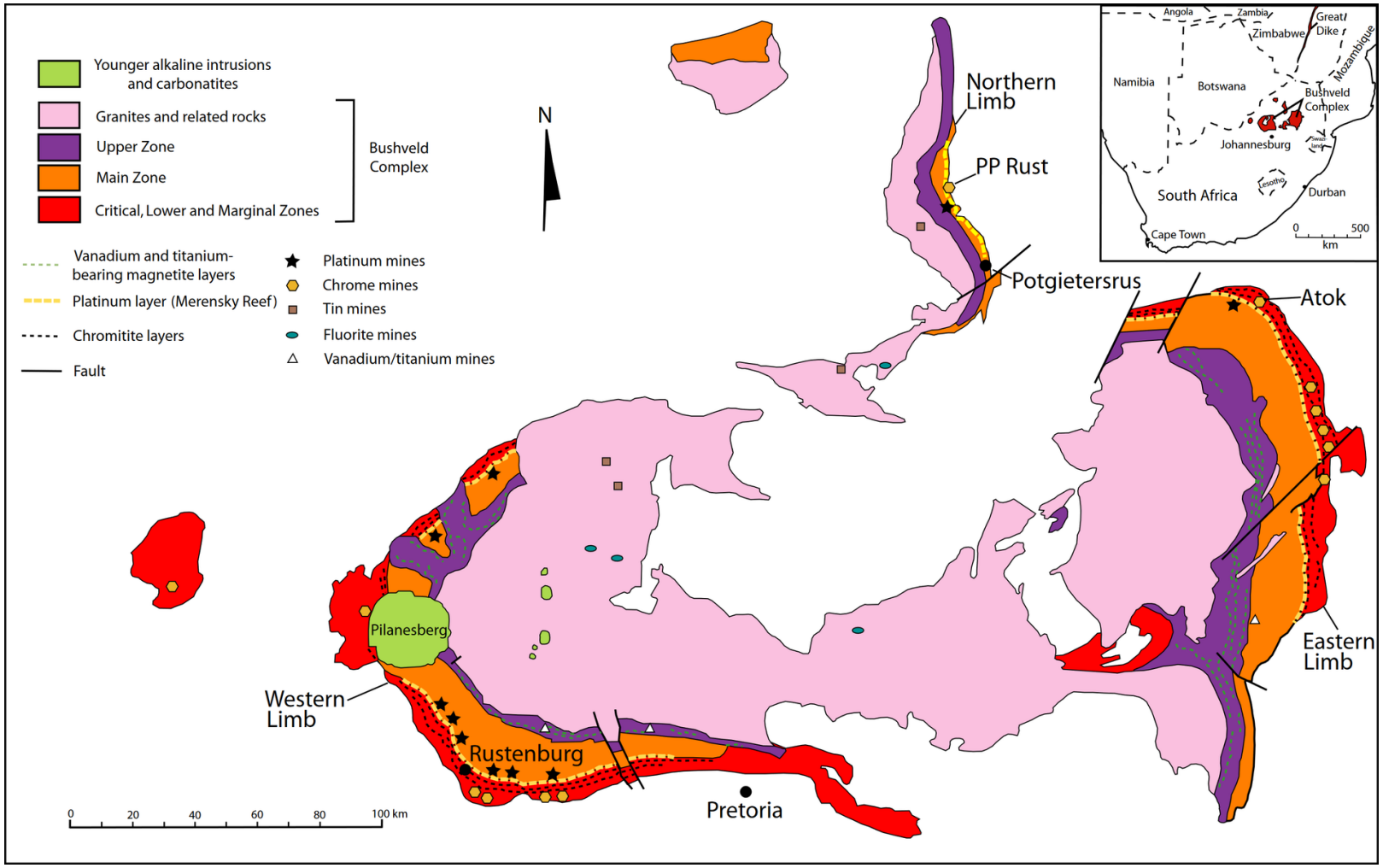
PGM	Merensky Reef [g/t]	UG2 [g/t]	Platreef [g/t]
Pt	3,25	2,46	1,26
Pd	1,38	2,04	1,38
Rh	0,17	0,54	0,09
Ru	0,44	0,72	0,12
Ir	0,06	0,11	0,02
Os	0,04	0,10	0,02
Au	0,18	0,02	0,10
Summe (PGM + Au)	**5,5**	**6,0**	**3,0**
Pt/Pd-Verhältnis	**2,4**	**1,2**	**0,9**

Table 5. Concentrate analyses.*

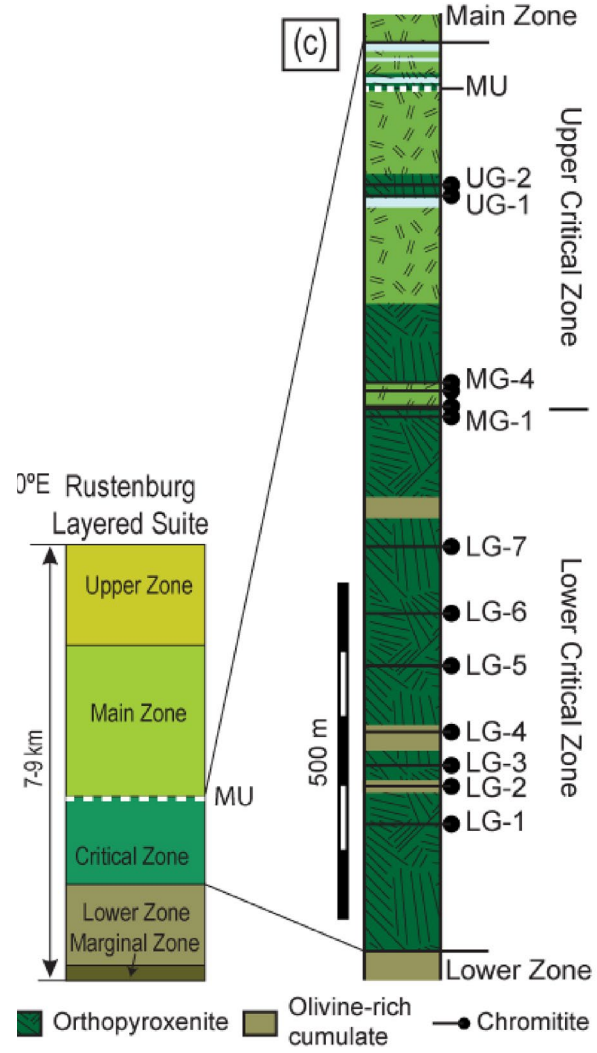
	Al_2O_3	CaO	Co	Cr_2O_3	Cu	FeO	MgO	Ni	S	SiO_2	PGM	Total
Amplats: Waterval	3.2	4.7	0.08	0.80	2.1	20	15	3.6	9	34	143	92
Amplats: Union	3.8	2.5	0.04	2.59	1.1	15	20	2.2	5	38	142	90
Impala	4.1	2.9	0.06	1.1	1.3	18	18	2.1	5.6	42	138	95
Lonmin: Merensky	1.8	2.8	0.08	0.4	2.0	23	18	3.0	9	41	130	101
Lonmin: UG2 blend	3.6	2.7	0.06	2.8	1.2	15	21	2.1	4.1	47	340	100
Northam	2.6	3.0	0.05	0.87	1.3	17	18	2.5	5.4	47	132	97

*All as percentages except PGM (g/t).

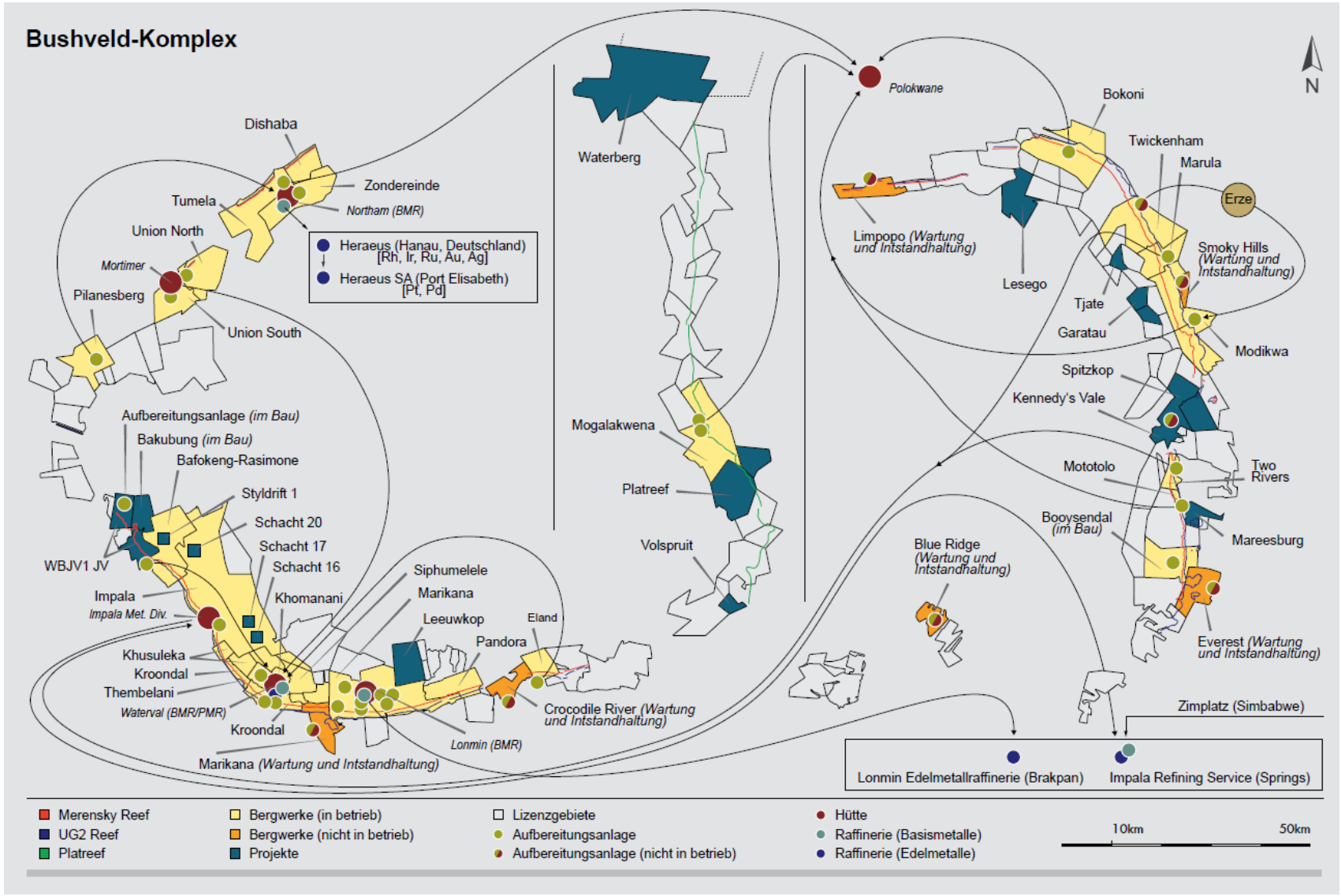
PGM Dominated Deposits (Bushveld Complex)



Source: Wikipedia 2021)



South Africa (Industry Structure)



- Foundation Sibanye Gold Ltd. 2013.
- Sibanye acquires Aquarius Platinum (Kroondal, Platinum Mile, Mimosa JV) in 2016.
- Sibanye buys Rustenburg operations from Anglo American for $330 mill.US.
- Sibanye buys Stillwater Mining for $2.2 bill.US.
- Sibanye acquires SFA Oxford (Metal Market Analytical Consulting Company).
- Sibanye acquires Lonmin Plc in 2019.
- Rise to largest platinum producer within 7 years ....
- Rise to second largest palladium producer….

Northern Limb (Bushveld Complex)

Mogalakwena Mine (Anglo Platinum) (Schmidt 2013)

Mogalakwena Mine (Anglo Platinum) (Schmidt 2013)

Source: Schmidt 2013

Northern Limb (Bushveld Complex)

Mogalakwena Mine (Anglo Platinum) (Schmidt 2013)

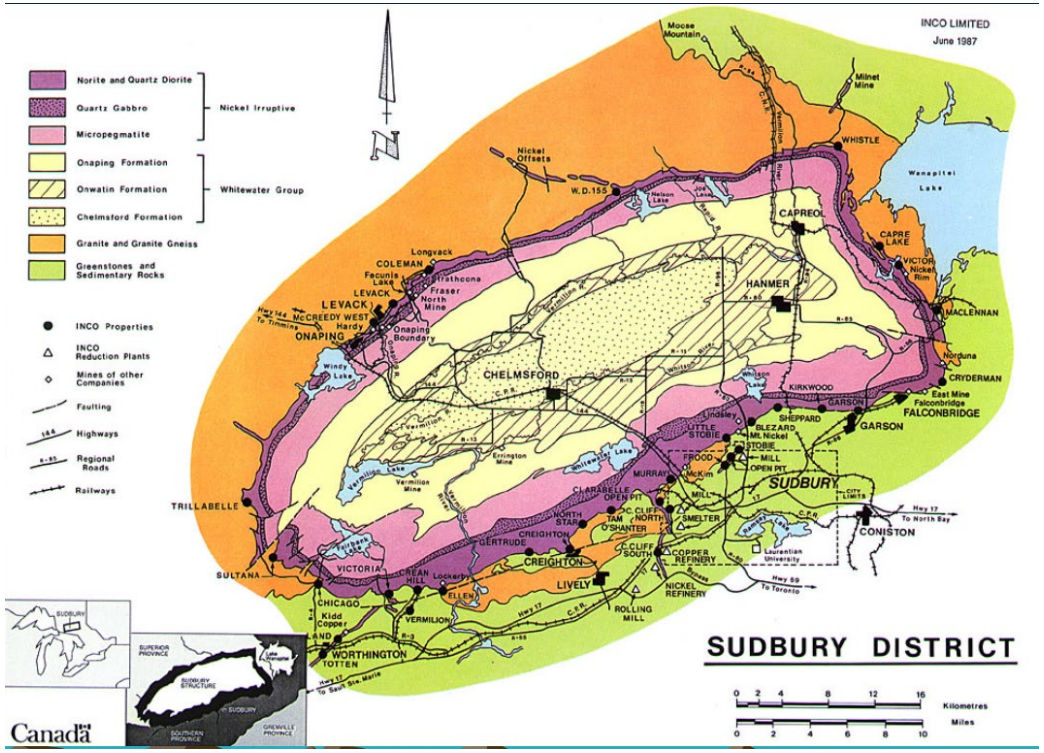
Nickel-Copper Dominated Deposits

Tab. 5: Nickel-Kupfer-dominierte, PGM-haltige Lagerstätten und Beispiele (Datenquelle: GUNN 2014).

Lagerstättentyp	Gehalte Ø [g/t]	Lagerstätten
An Impaktstrukturen gebunden	5 – 7 (Pt + Pd)	Sudbury (Kanada)
An Riftzonen und kontinentale Flutbasalte gebunden	Ø 7,3 (Pd), Ø 1,8 (Pt) [Norilsk]	Norilsk-Talnakh (Russische Föderation), Jinchuan (China)
An Komatiite gebunden	Im ppb-Bereich; lokal > 1 (Pt + Pd)	Kambalda (Australien), Pechenga-Distrikt (Russische Föderation), Thompson-Belt u. Ugava-Belt (Kanada)

Tab. 6: Weitere PGM-führende Lagerstätten (Datenquelle: GUNN 2014).

Lagerstättentyp	Lagerstätten
Alaska-Typ; Alaska-Ural-Typ	Nizhny Tagil (Russische Föderation)
Placer	Ural (Russische Föderation), Choco River (Kolumbien)
An Ophiolite gebundene Lagerstätten	Unst (Großbritannien), Zambales (Philippinen)
An Laterite gebundene Lagerstätten	Yubdo (Äthiopien)
An hydrothermale Lagerstätten gebunden	New Rambler (USA), Rathbun Lake (Kanada)
An Diskordanzen gebundene Lagerstätten	Coronation Hill (Australien), Serra Pelada (Brasilien)
Porphyr-Typ	Elatsite (Bulgarien), Skourries (Griechenland)
Sedimentgebundene Lagerstätten	Kupferschiefer (Deutschland, Polen)
An Karbonatite gebundene Lagerstätten	Palabora (Südafrika), Ipanema (Brasilien)



Source: https://faculty.washington.edu/dersh/Files/Project2009/Sudbury.pdf

PGM Resources

Country Ranking by Reserves & Resources

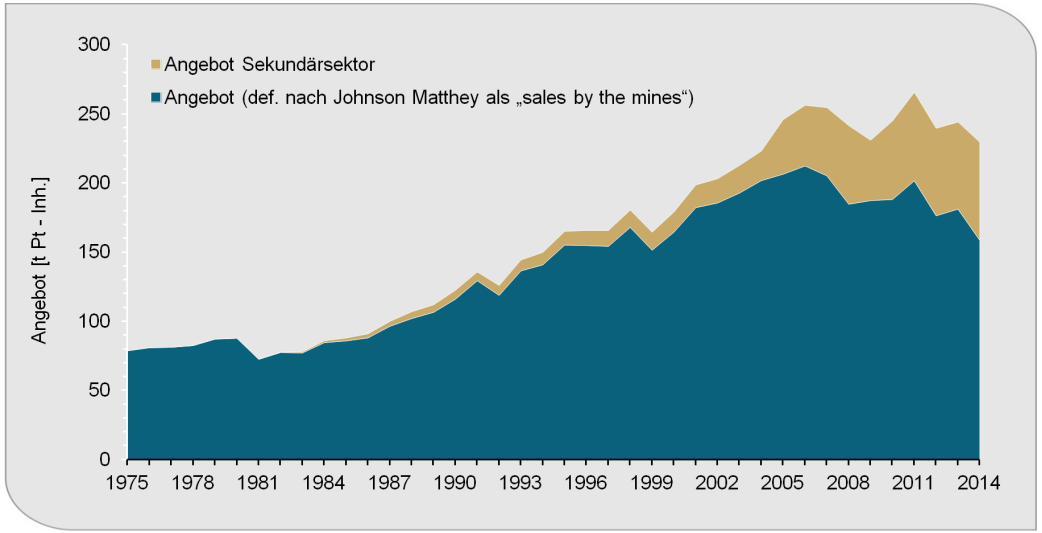
COUNTRY	AGGREGATE PLATINUM IN RESERVES & RESOURCES (OZ)	ACTIVE PROJECTS
South Africa	1.412.764.522	46
Zimbabwe	97.670.864	4
Russia	92.968.541	8
Canada	16.877.469	25
USA	13.800.000	4
Finland	5.284.500	4
Australia	5.256.550	9
China	4.022.000	2
Botswana	2.488.009	2
Greenland	677.784	1

Largest Projects by Reserves & Resources

PROPERTY	COMMODITY(S)	PLATINUM CONTAINED IN RESERVES & RESOURCES (OZ)
Mogalakwena	Pt, Pd, Rh, Ir, Ru, Au, Cu, Ni	270.400.000
Marikana	Pt, Pd, Rh, Au, Ru, Ir, Cu, Ni	130.516.000
Twickenham	Pt, Pd, Rh, Au, Cu, Ni	116.700.000
Zondereinde	Pt, Pd, Rh, Au, Ni, Cu, Ir, Ru, Chromite	104.030.000
Booysendal South	Pt, Pd, Rh, Au, Ru, Ni, Ir, Chromite, Cu	102.330.000
Amandelbult	Pt, Pd, Rh, Ir, Ru, Au, Cu, Ni	94.500.000
Rustenburg	Pt, Pd, Rh, Au, Ni, Cu, Ir, Co	82.941.000
Bokoni	Pt, Pd, Rh, Au, Ni, Cu, Ir, Ru, Chromite, Co	74.107.700
Der Brochen	Pt, Pd, Rh, Au, Cu, Ni	71.600.000
Polar Division	Ni, Cu, Pd, Rh, Pt, Co, Au, Ag, Ir, Os, Ru, Se, Te	69.831.000

Source: S&P Global 2022

Platinum Supply 1975 - 2021



Supply tonnes[1]	2015	2016	2017	2018	2019	2020	2021
South Africa	142.2	136.6	138.4	138.9	136.8	99.5	143.4
Russia[2]	20.8	22.2	22.4	21.4	22.4	20.6	19.8
North America	11.0	11.6	11.5	10.8	10.9	10.5	8.6
Zimbabwe[3]	12.5	15.2	14.5	14.7	14.0	15.2	14.5
Others[3]	4.9	5.0	4.9	4.7	4.9	6.2	6.4
Total supply	**191.4**	**190.6**	**191.7**	**190.5**	**189.0**	**152.0**	**192.7**

Recycling tonnes[6]	2015	2016	2017	2018	2019	2020	2021
Autocatalyst	-35.6	-35.2	-38.8	-41.4	-43.3	-36.1	-38.4
Electronics	-0.9	-1.0	-1.1	-1.2	-1.2	-1.2	-1.4
Jewellery	-17.9	-23.0	-23.2	-21.7	-20.2	-13.8	-11.8
Total recycling	**-54.4**	**-59.2**	**-63.1**	**-64.3**	**-64.7**	**-51.1**	**-51.6**

Demand 2021: 210t

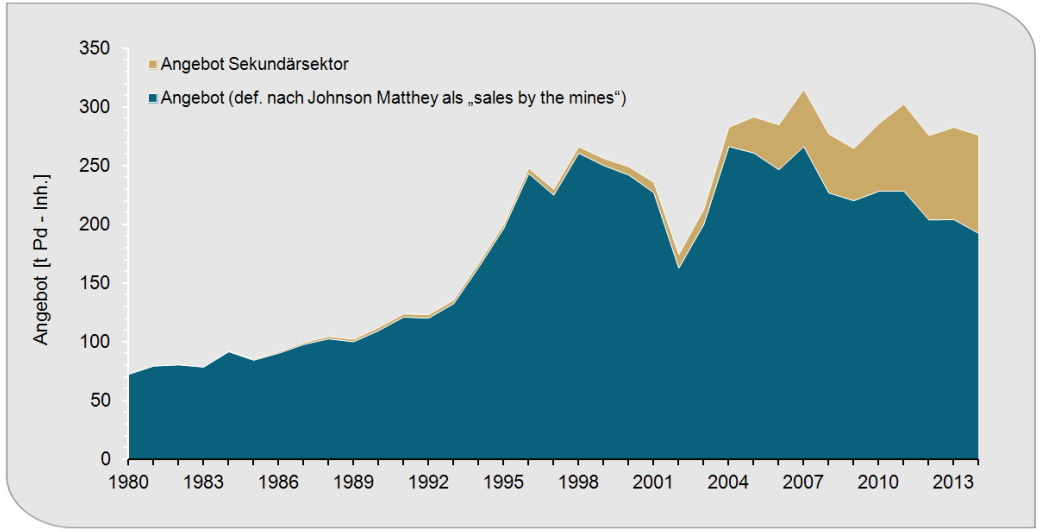
Demand tonnes[4]	2017	2018	2019	2020	2021	2022
Total gross demand	**248.1**	**244.7**	**260.3**	**223.9**	**210.0**	**211.6**

Supply 2021: 244.3t

Secondary: 21.1%

Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Palladium Supply 1980 - 2021



Supply tonnes[1]	2015	2016	2017	2018	2019	2020	2021
South Africa	83.4	79.9	79.2	79.1	81.7	60.3	82.5
Russia[2]	75.7	86.5	76.3	92.6	92.9	84.8	83.6
North America	27.2	28.5	29.7	30.4	30.6	29.0	27.2
Zimbabwe[3]	10.0	12.3	12.0	12.2	11.8	12.1	12.2
Others[3]	4.5	4.0	4.1	4.2	4.4	5.6	5.8
Total supply	**200.8**	**211.2**	**201.3**	**218.5**	**221.4**	**191.8**	**211.3**

40% in 2021

Recycling tonnes[6]	2015	2016	2017	2018	2019	2020	2021
Autocatalyst	-60.7	-61.7	-73.4	-81.6	-91.0	-83.9	-90.0
Electronics	-14.8	-15.0	-14.9	-14.8	-14.7	-12.8	-14.3
Jewellery	-1.4	-0.7	-0.6	-0.4	-0.4	-0.3	-0.3
Total recycling	**-76.9**	**-77.4**	**-88.9**	**-96.8**	**-106.1**	**-97.0**	**-104.6**

Demand 2021: 314.1t

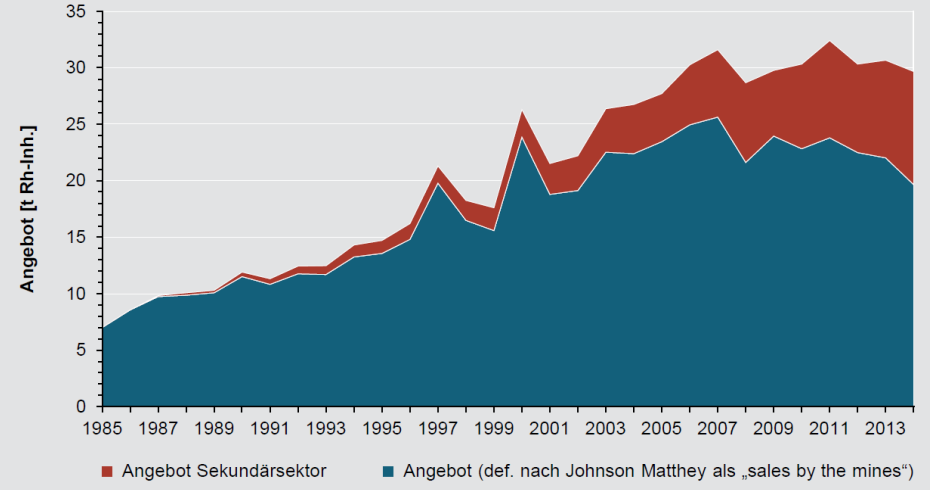
Demand tonnes[4]	2017	2018	2019	2020	2021	2022
Total gross demand	**312.6**	**322.0**	**356.0**	**309.6**	**314.1**	**315.6**

Supply 2021: 315.9t

Secondary: 33.1%

Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Rhodium Supply 1985 - 2021



Supply tonnes[1]	2015	2016	2017	2018	2019	2020	2021
South Africa	19.0	19.1	19.0	19.2	19.4	14.0	20.1
Russia[2]	2.5	2.6	2.4	2.1	2.1	2.0	1.7
North America	0.8	0.7	0.7	0.7	0.7	0.7	0.5
Zimbabwe[3]	1.1	1.4	1.3	1.3	1.2	1.3	1.3
Others[3]	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total supply	**23.6**	**24.0**	**23.6**	**23.5**	**23.6**	**18.2**	**23.8**

Recycling tonnes[6]	2015	2016	2017	2018	2019	2020	2021
Autocatalyst	-8.7	-8.6	-9.6	-10.3	-11.1	-10.5	-11.5
Total recycling	**-8.7**	**-8.6**	**-9.6**	**-10.3**	**-11.1**	**-10.5**	**-11.5**

Demand 2021: 35.3t

Demand tonnes[4]	2017	2018	2019	2020	2021	2022
Total gross demand	**32.1**	**32.9**	**36.3**	**32.2**	**32.2**	**33.7**

Supply 2021: 35.3t

Secondary: 32.5%

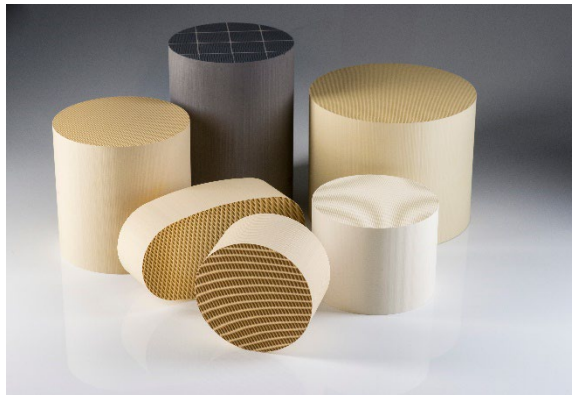
Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Recycling

EOL Recycling Raten[1)]		Sektor spezifische EOL Recycling Raten					Schmuck & Münzen[5)]
		Fahrzeuge[2)]	Elektronik	Industrie[3)]	Zahntechnik	Übrige Anwendungen[4)]	
Platin (Pt)	60 – 70	50 – 55	0 – 5	80 – 90	15 – 20	10 – 20	90 – 100
Palladium (Pd)	60 – 70	50 – 55	5 – 10	80 – 90	15 - 20	15 – 20	90 – 100
Rhodium (Rh)	50 – 60	45 – 50	5 – 10	80 – 90	-	30 – 50	40 – 50
Osmium (Os)	keine nennenswerte Endanwendung						
Iridium (Ir)	20 – 30	-	0	40 – 50	-	5 – 10	-
Ruthenium (Ru)	5 – 15	-	0 – 5	40 – 50	-	1 – 5	-

[1)] Gesamt ohne Schmuck und Münzen, [2)] Autoabgaskatalysatoren, Zündkerzen (ohne Fahrzeugelektronik), [3)] Beinhaltet Prozesskatalysatoren, [4)] Beinhaltet: Dekorationen, Medizintechnik, Sensoren, Tiegel, [5)] Beinhaltet Medaillen und Silberwaren

Demand Platinum 2017 - 2021

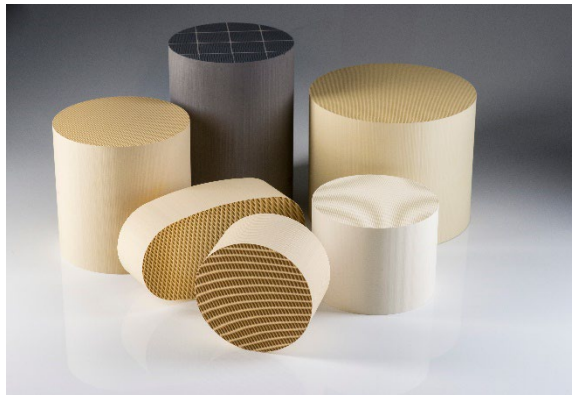


Demand tonnes[4]	2017	2018	2019	2020	2021	
Automotive[4]	95.3	87.5	80.7	63.6	73.1	34.8%
Chemical	14.1	20.3	20.7	19.2	19.9	
Dental & biomedical[5]	7.4	7.5	7.9	7.2	7.9	
Electrical & electronics[4]	6.9	7.1	6.7	6.9	8.2	
Glass	9.8	15.6	13.7	14.8	28.4	
Investment	11.2	2.1	35.2	31.8	-0.9	
Jewellery[4]	74.2	70.2	64.5	51.5	46.0	21.9%
Petroleum	7.1	11.8	8.1	10.4	7.3	
Pollution control	5.7	6.1	5.9	5.5	6.3	
Other	16.4	16.5	16.9	13.0	13.8	
Total gross demand	**248.1**	**244.7**	**260.3**	**223.9**	**210.0**	

Source: Umicore 2013

Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Demand Palladium 2017 - 2021

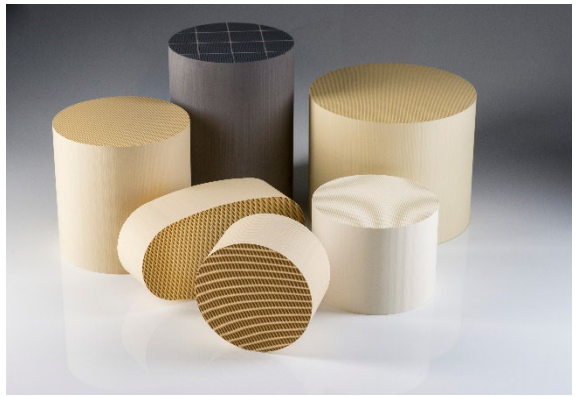


Source: Umicore 2013

Demand tonnes[4]	2017	2018	2019	2020	2021	
Automotive[4]	262.0	274.8	300.2	264.5	259.4	82.6%
Chemical	13.4	18.8	15.9	16.3	18.3	
Dental & biomedical	12.4	11.2	10.0	7.1	6.6	
Electrical & electronics[4]	26.2	23.9	22.1	19.7	20.3	6.4%
Investment	-12.0	-17.8	-2.7	-5.9	0.6	
Jewellery[4]	5.2	4.6	4.0	2.7	2.8	
Pollution control	2.5	2.8	2.7	2.3	3.0	
Other	2.9	3.7	3.8	2.9	3.1	
Total gross demand	**312.6**	**322.0**	**356.0**	**309.6**	**314.1**	

Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Demand Rhodium & Iridium 2017 - 2021



Demand tonnes[4]	2017	2018	2019	2020	2021
Automotive[4]	25.8	28.0	32.2	29.8	29.4
Chemical	2.4	2.0	1.8	1.8	1.7
Electrical & electronics	0.1	0.1	0.2	0.2	0.2
Glass	3.2	3.2	1.4	0.1	0.5
Other	0.6	-0.4	0.7	0.3	0.4
Total gross demand	**32.1**	**32.9**	**36.3**	**32.2**	**32.2**

91.3%

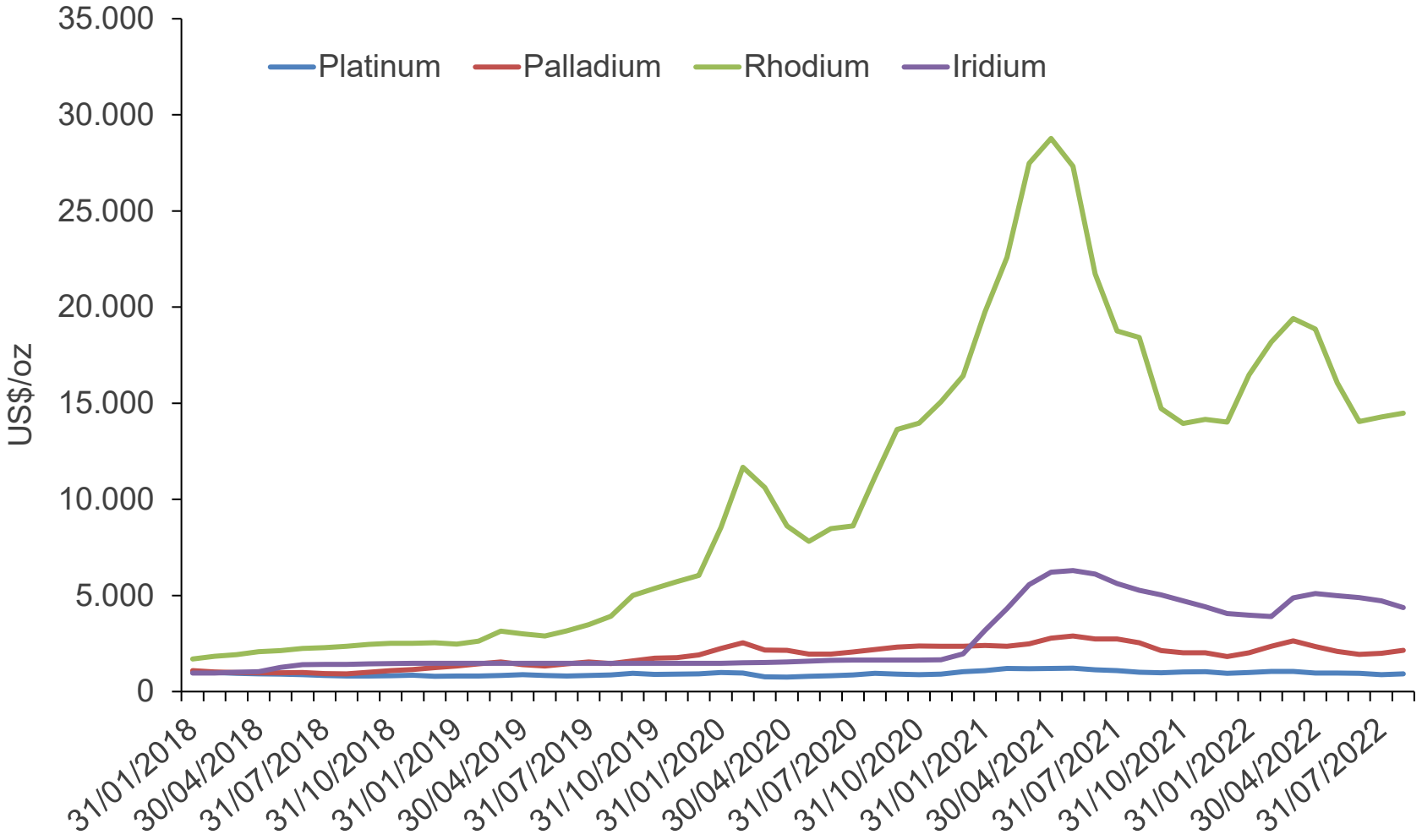
Source: Umicore 2013

Demand tonnes[4]	2017	2018	2019	2020	2021
Chemical	0.5	0.7	0.7	0.8	0.8
Electrical & electronics	2.1	1.4	1.5	1.8	1.7
Electrochemical	2.5	2.3	2.6	2.7	2.7
Other	2.7	3.2	2.8	2	2
Total gross demand	**7.8**	**7.6**	**7.6**	**7.3**	**7.2**

37.5%

Source: https://matthey.com/documents/161599/509428/PGM-market-report-May-2022.pdf/542bcada-f4ac-a673-5f95-ad1bbfca5106?t=1655877358676

Price Developement 01/2018 – 08/2022



31.08.2022

- Platinum: 920 $US/oz
- Palladium: 2,155 $US/oz
- Rhodium: 14,482 $US/oz
- Iridium: 4,380 $US/oz

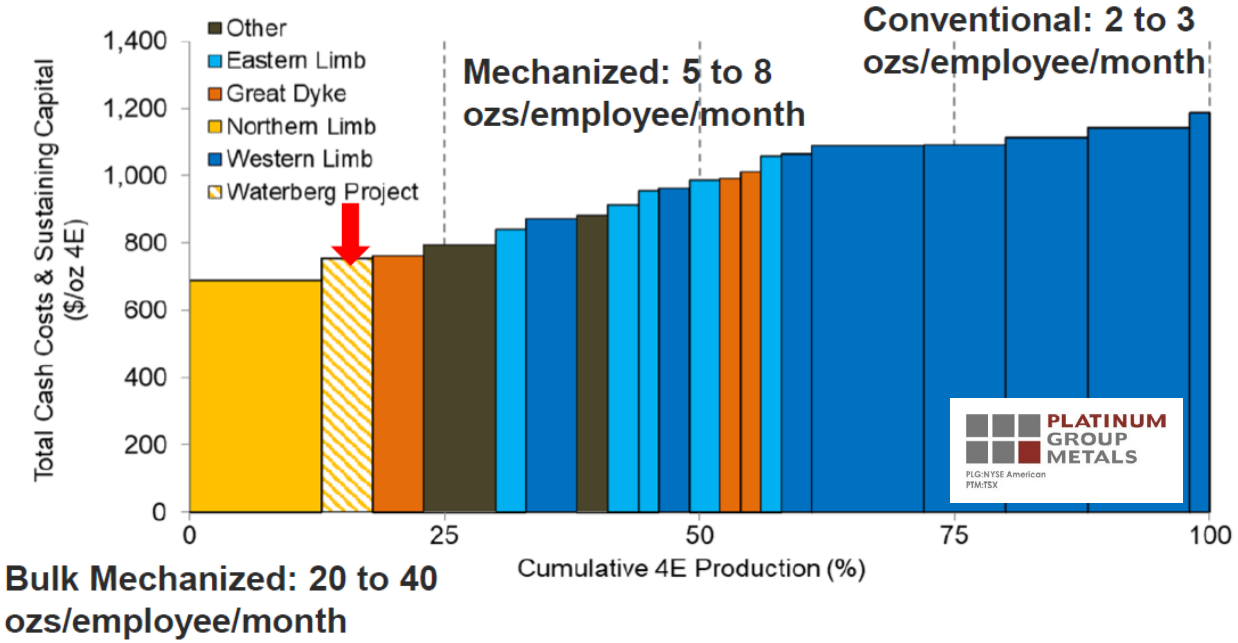
Source: http://www.platinum.matthey.com/prices/price-charts

Cash Cost PGM Industry And Implications

PGM Industry Cost Curve

Waterberg Total All-In Cost: $767 USD/4E Ounce

Bottom of Curve and Low Sensitivity to Labour Costs



SOURCE: Metals Focus. Data for Waterberg is based on Platinum Group projections and is not representative of Metals Focus view.

At what platinum price are mine operation economically viable?

It is rather about the "production basket".

31.08.2022

- Platinum: 920 $US/oz
- Palladium: 2,155 $US/oz
- Rhodium: 14,482 $US/oz
- Iridium: 4,380 $US/oz

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DERA Rohstoffinformationen

Update 2023

Rohstoffrisikobewertung – Platingruppenmetalle

Platin, Palladium, Rhodium

7. Marktplatz Zulieferer
Wasserstoff- und Brennstoffzellentechnologie
31. August 2022

Rohstoffe für Wasserstofftechnologien – Fokus Platingruppenelemente –

Vielen Dank

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