A GEOCHEMICAL CHARACTERIZATION OF THE GARDNOS IMPACTOR.

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[1]Earth System Sciences, Vrije Universiteit Brussel, B 1050 Brussels, Belgium (Steven.Goderis@vub.ac.be), [2]Natural History Museum, University of Oslo, N-0316 Oslo, Norway, [3]Wisbyer Str. 35, D-13189 Berlin, Germany, [4]Dept. of Geosciences, University of Oslo, Norway, [5]Dept. of Mineralogy, Natural History Museum, Berlin, D-10099 Berlin, Germany, [6]GeoForschungsZentrum Potsdam, D-14473 Potsdam, Germany.

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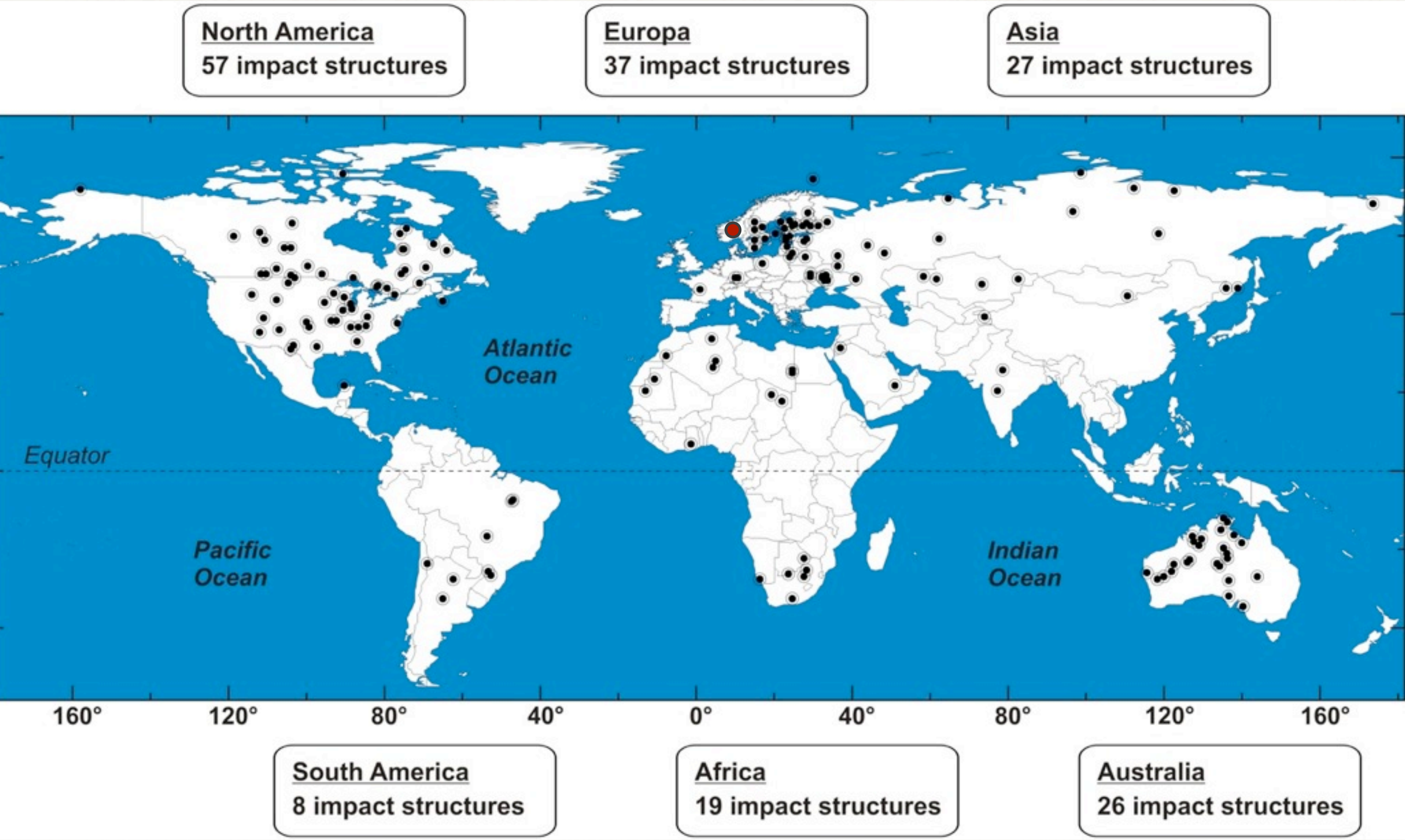


Location of 176 currently recognized terrestrial impact structures,
Koeberl (2007) for only 45 structures a type of projectile has been proposed

Data from Earth Impact Database (2008), figure courtesy of Dr. L. Ferrière.

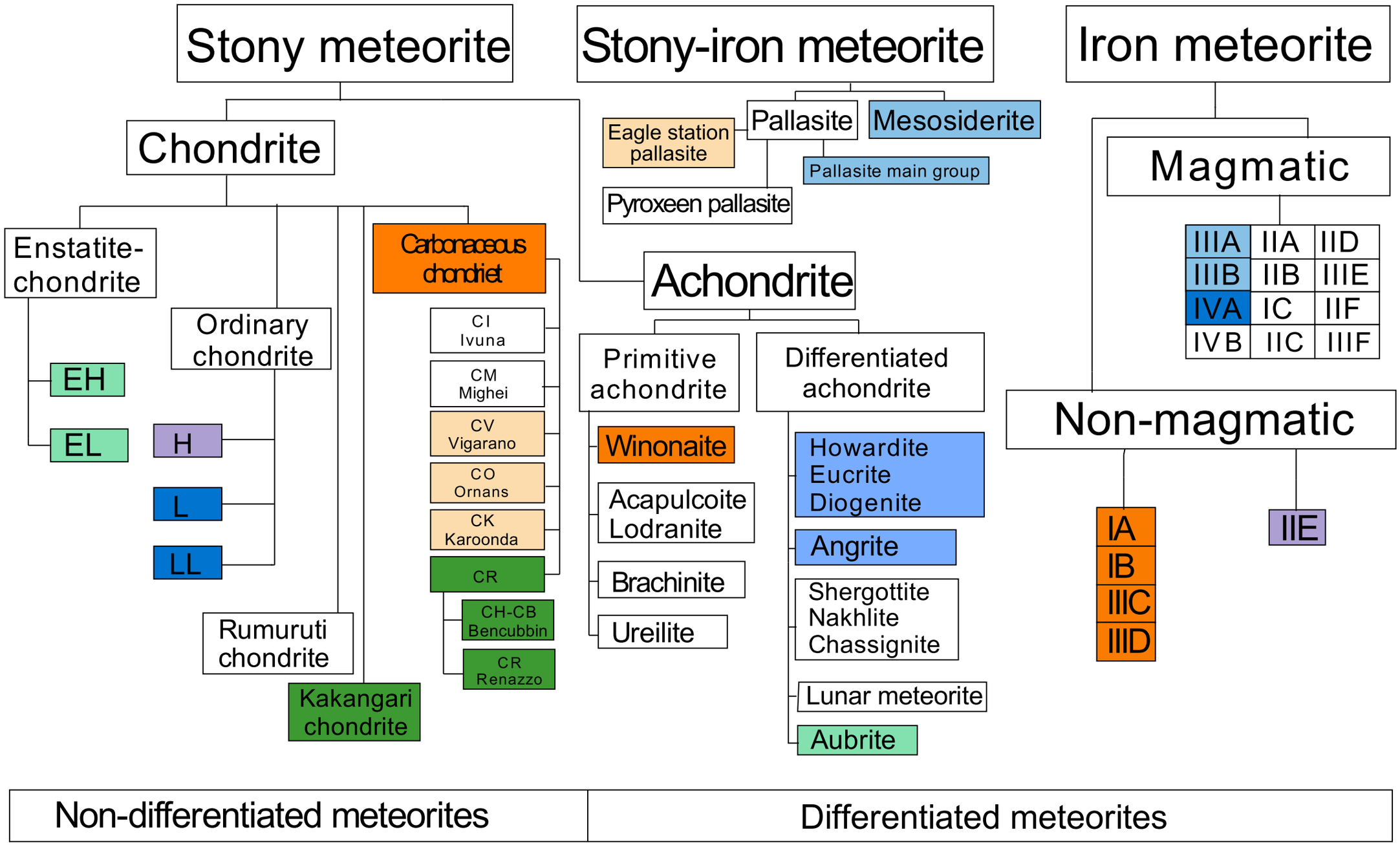
Projectile ID using crater impact melts & ejecta layers

Meteoritic contribution to the melt rock between < 0.1 to 7 wt%

Ejecta layers enriched in PGE

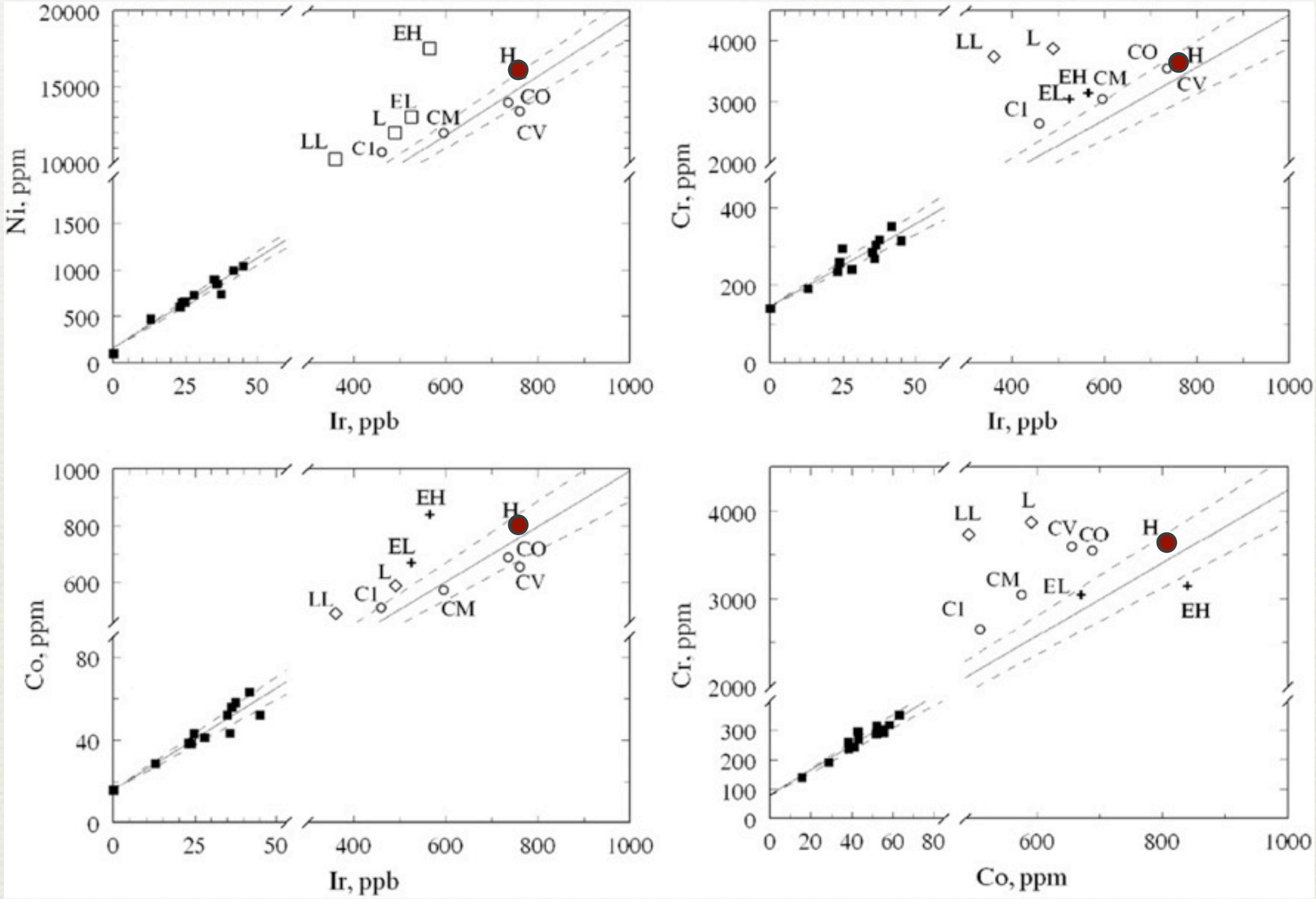
Detect and identify type of projectile: siderophile elements and PGE elemental ratios, and osmium and chromium isotopes

Compare projectile with meteorite classification…



… and then to asteroid spectral classification

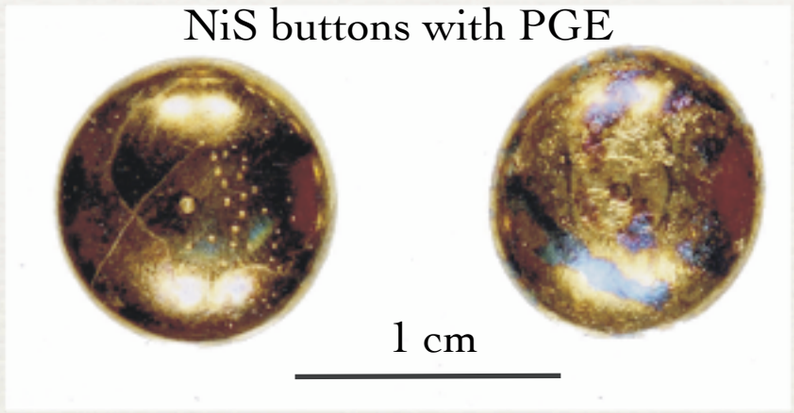
Siderophile elements



Lappajärvi ~ H chondrite? (Koeberl et al., 2007)

Platinum Group Elements, analytical procedure

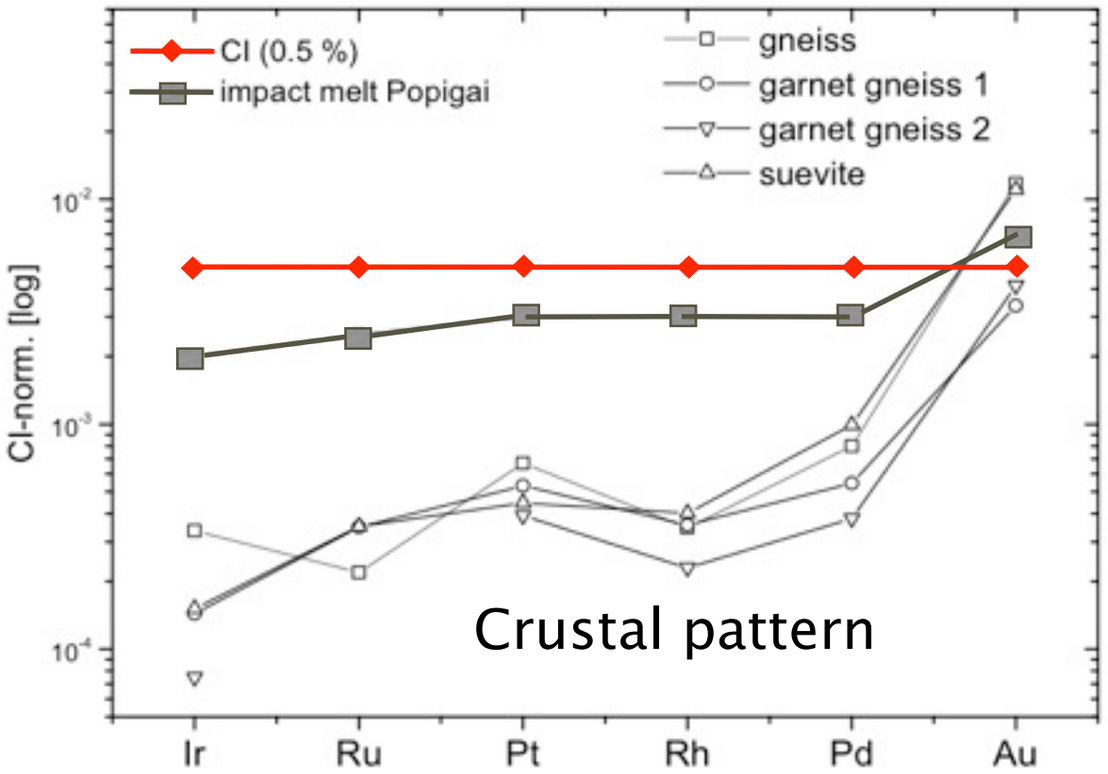
- Nickel sulfide fire assay method combined with ICP-MS, analytical facilities at GFZ, Potsdam



- Advantages:
  - ✓ Low detection limit (60 ppt Ru, 20 ppt Rh, 190 ppt Pd, 60 ppt Ir, 70 ppt Pt)
  - ✓ Up to 70 g per analysis (less nugget effect)
  - ✓ Very good reproducibility down to 5 to 10 g material
  - ✓ All PGE (except Os) determined at once

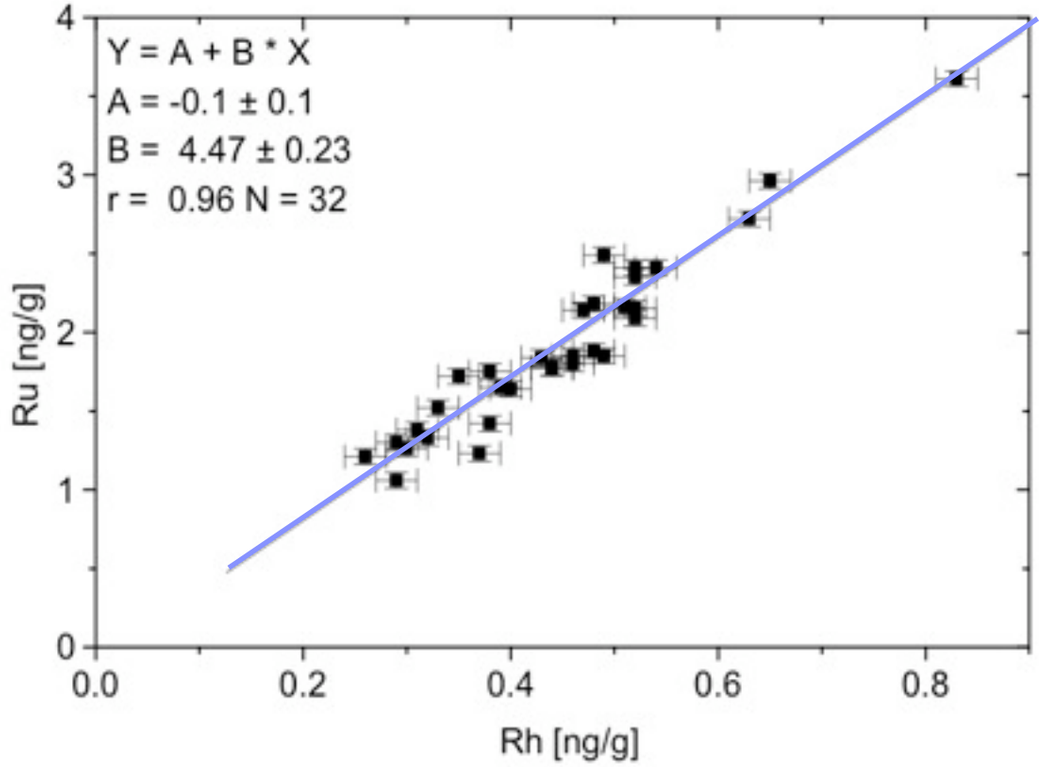
PGE, Cr, Ni system

Tagle and Claeys 2005

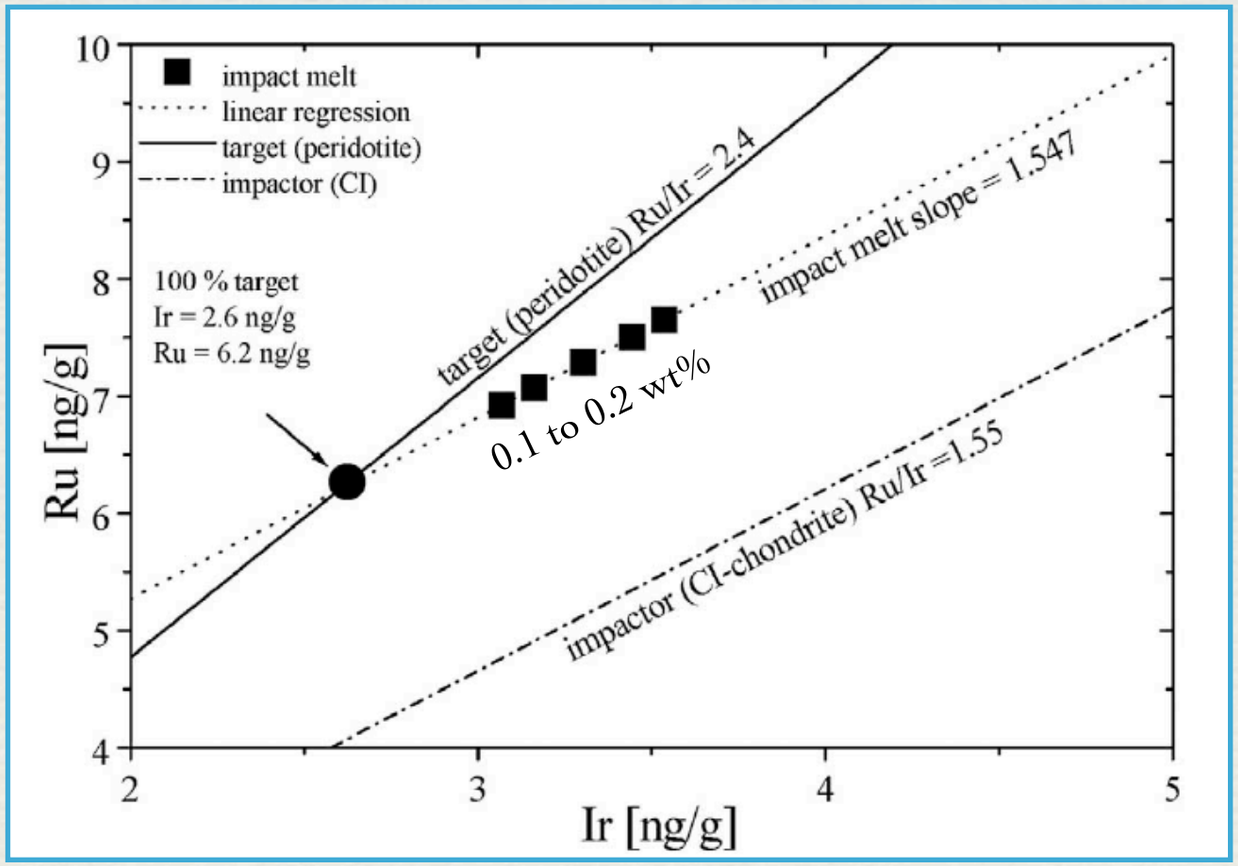


Pattern vs CI

No need to subtract PGE target



Elemental ratios: Ru/Rh etc.



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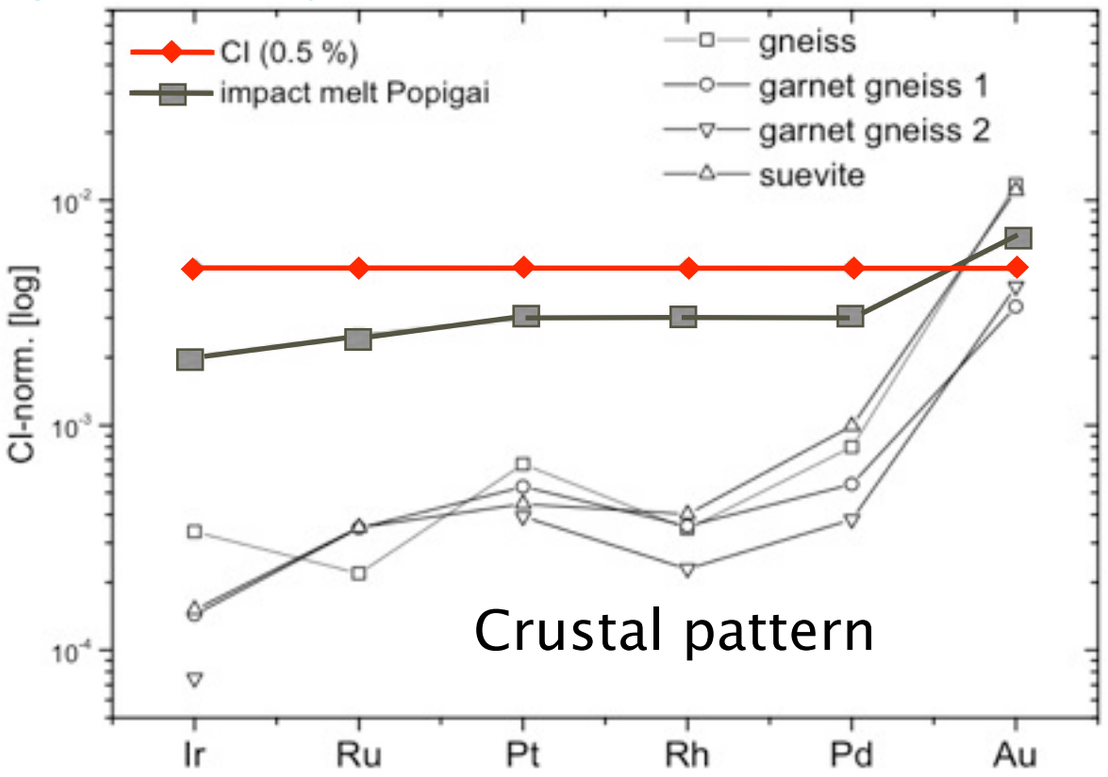
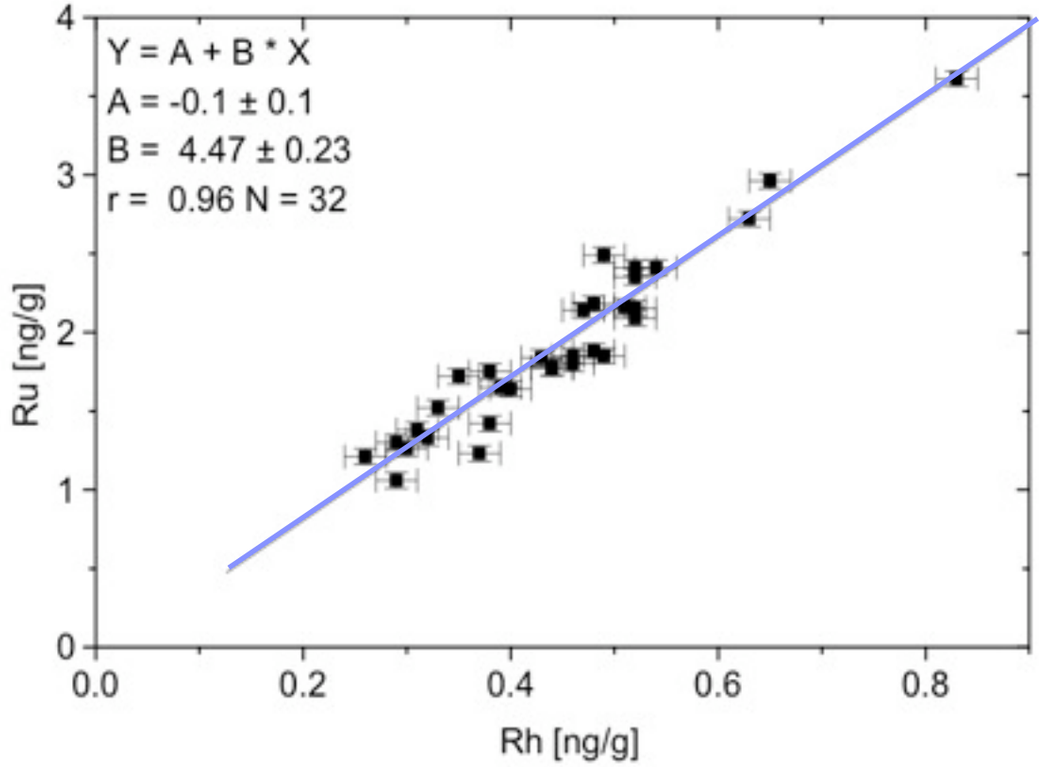


Pattern vs CI

Ideal cases ID projectile down to type of chondrite

No need to subtract PGE target



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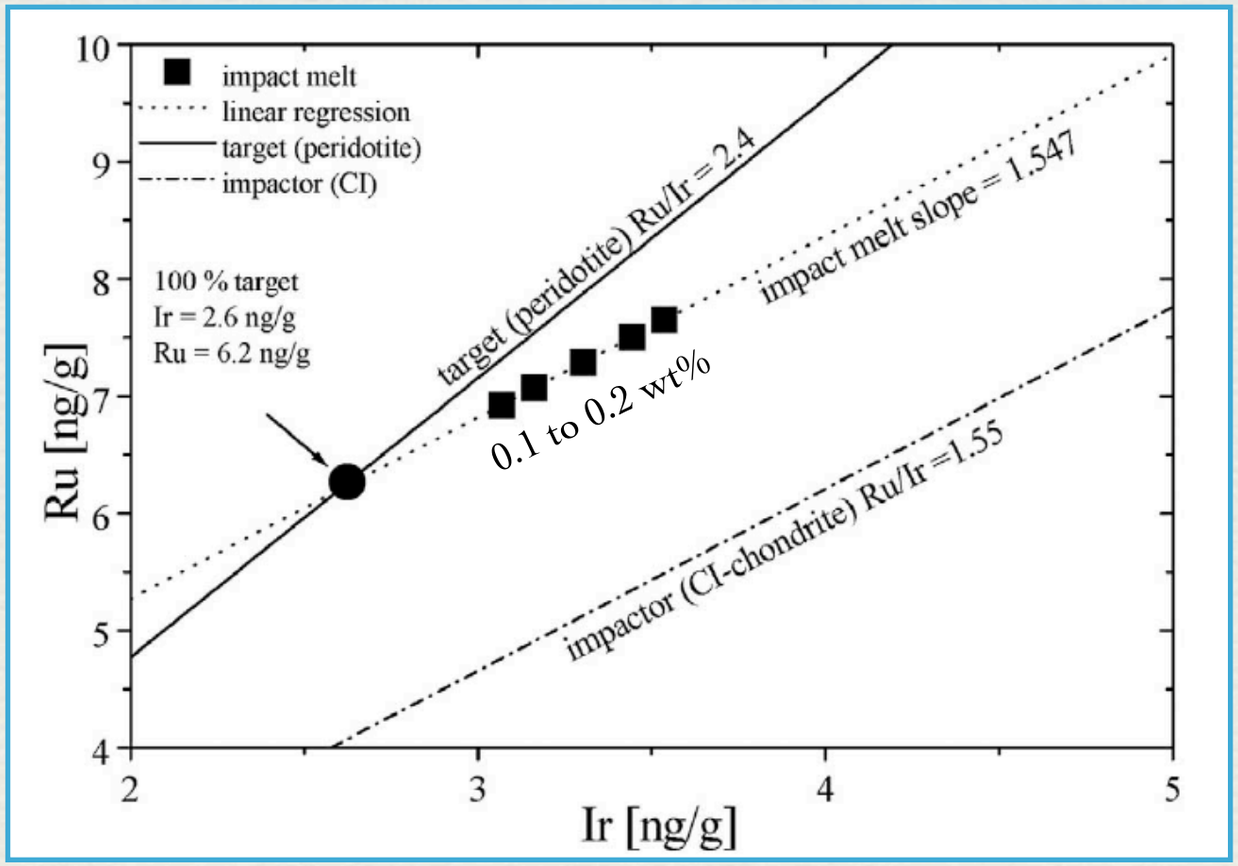
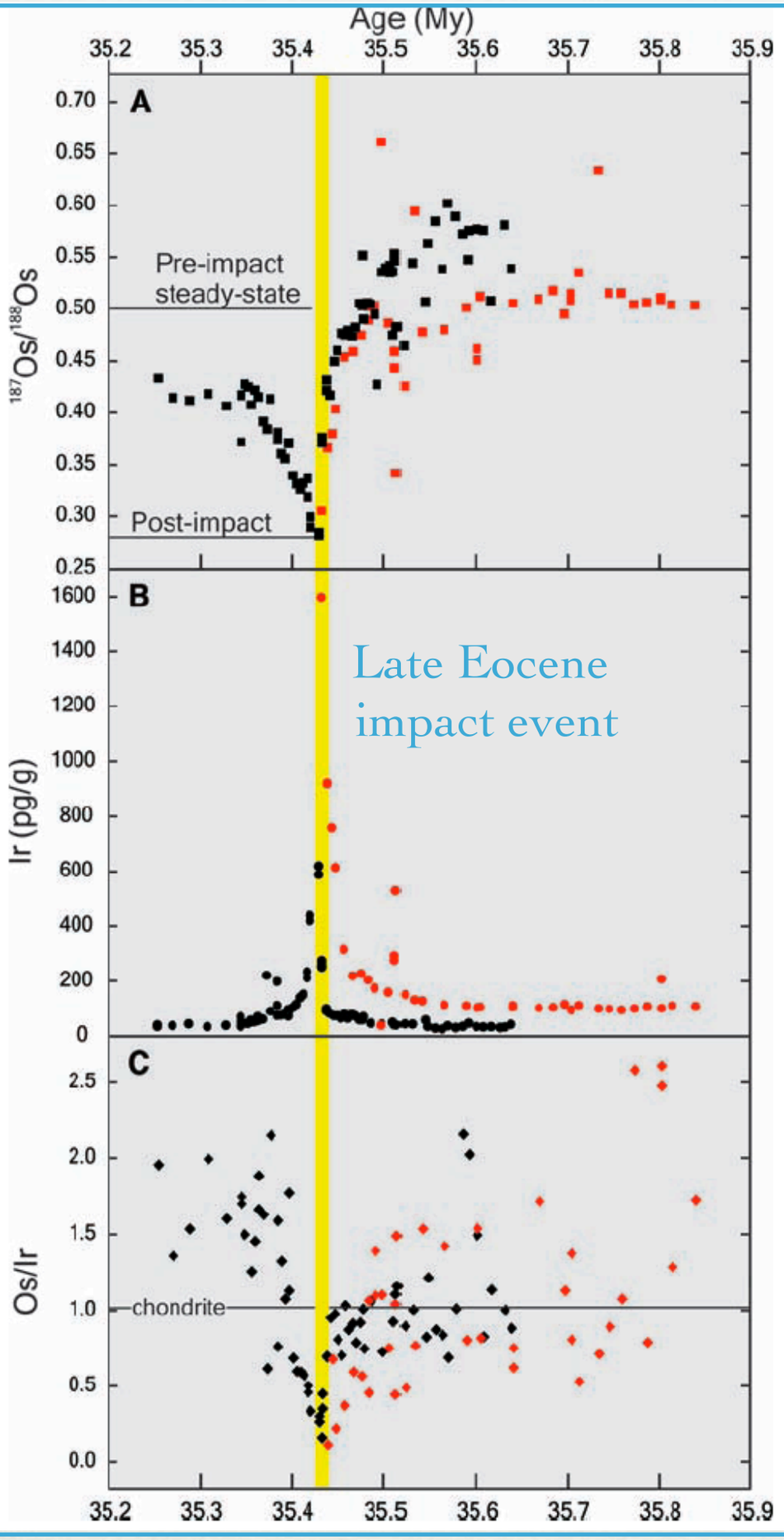


Compared PGE elemental ratios in impact melt or ejecta with meteorite database (Tagle 2004; Tagle and Hecht 2008)

	Number of analyses in the database						
Type	Total	Ir	Ru	Pt	Rh	Pd	Ni
Chondrite	605	549	269	163	31	158	386
Achondrite*	600	168	12	3	0	5	315
Iron	2,002	1,361	231	458	133	194	1,706
Total	**3,207**	**2,078**	**512**	**624**	**164**	**357**	**2,407**

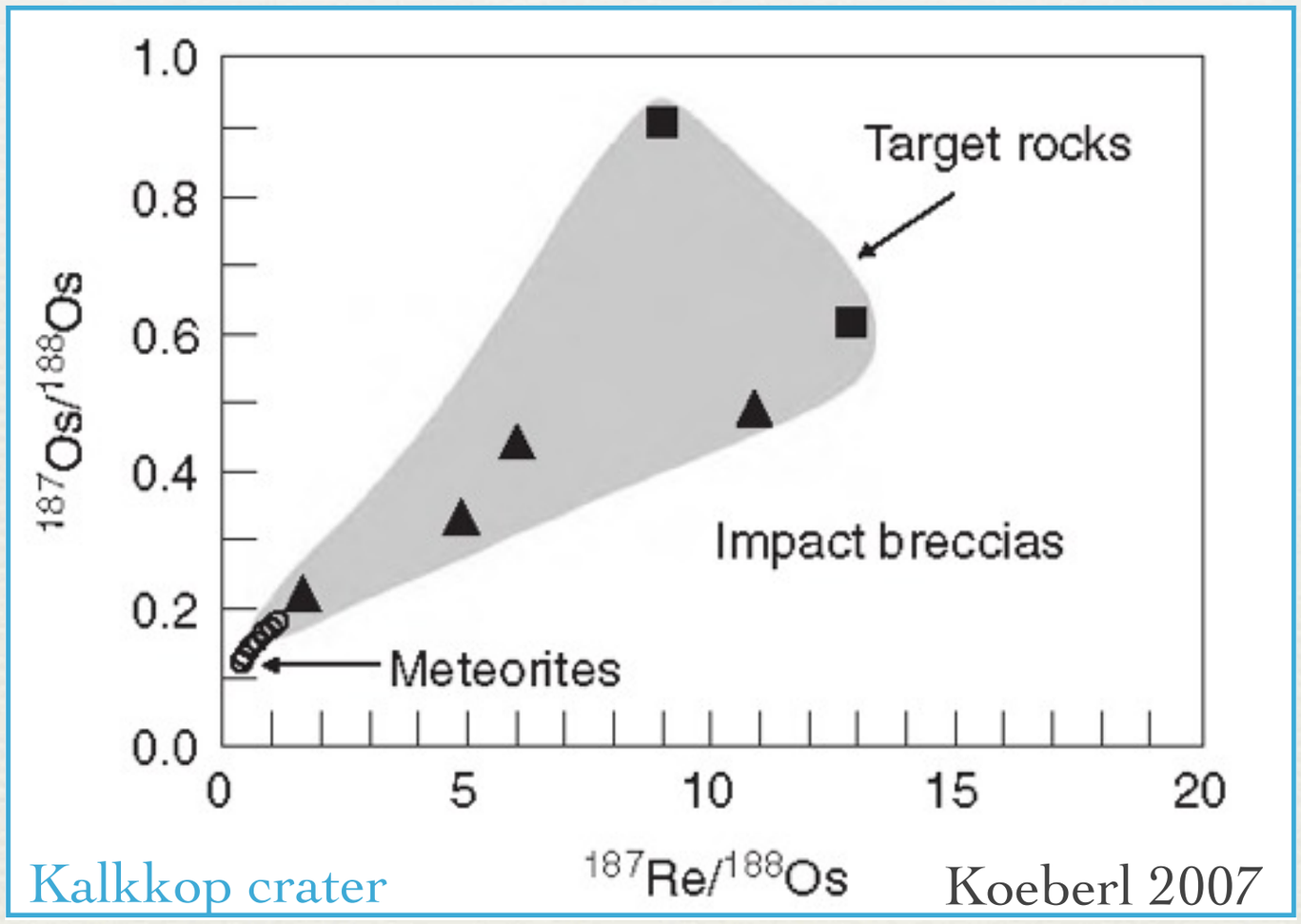
* Primitive & differentiated

- CC, OC & EC have different patterns
- Iron meteorites are richer in PGE but depleted in Cr compared to CI chondrites
- Some analyses by NAA, on small samples, nugget effect ?
- Continuously refined by new measurements



Osmium system

Highly sensitive tool for detection of ET material, not for ID! $^{187}Re \xrightarrow{\beta} {}^{187}Os$ (42.3 Ga)



Kalkkop crater

Koeberl 2007

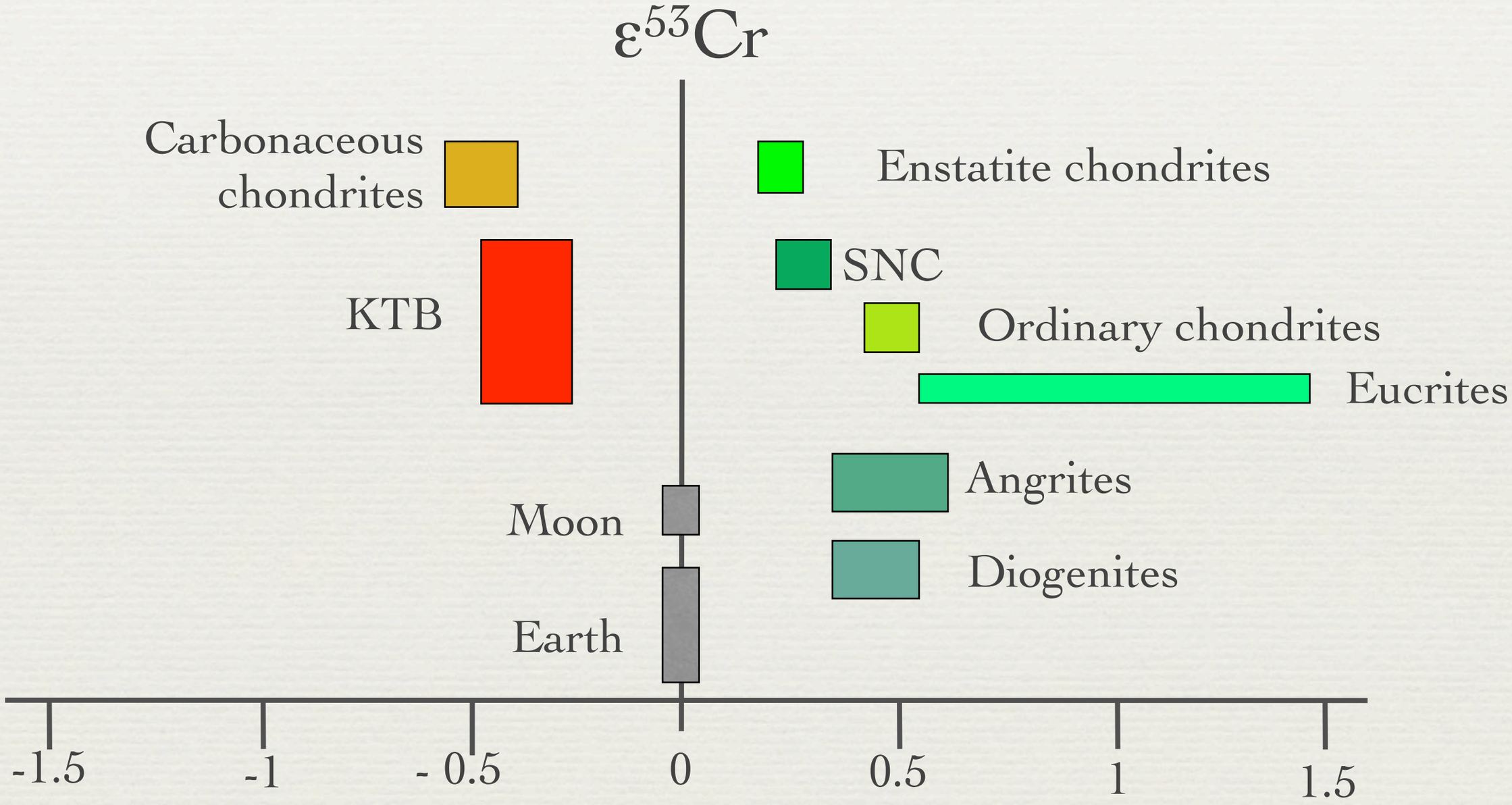
+ Projectile size estimation next to Ir fluence!

Paquay et al. 2008

Chromium system

$^{53}Mn \xrightarrow{E.C} {}^{53}Cr$ (3.7 Ma) $^{53}Cr/^{52}Cr = 0$ std Earth

Meteorites differ due to early planetary Mn/Cr fractionation



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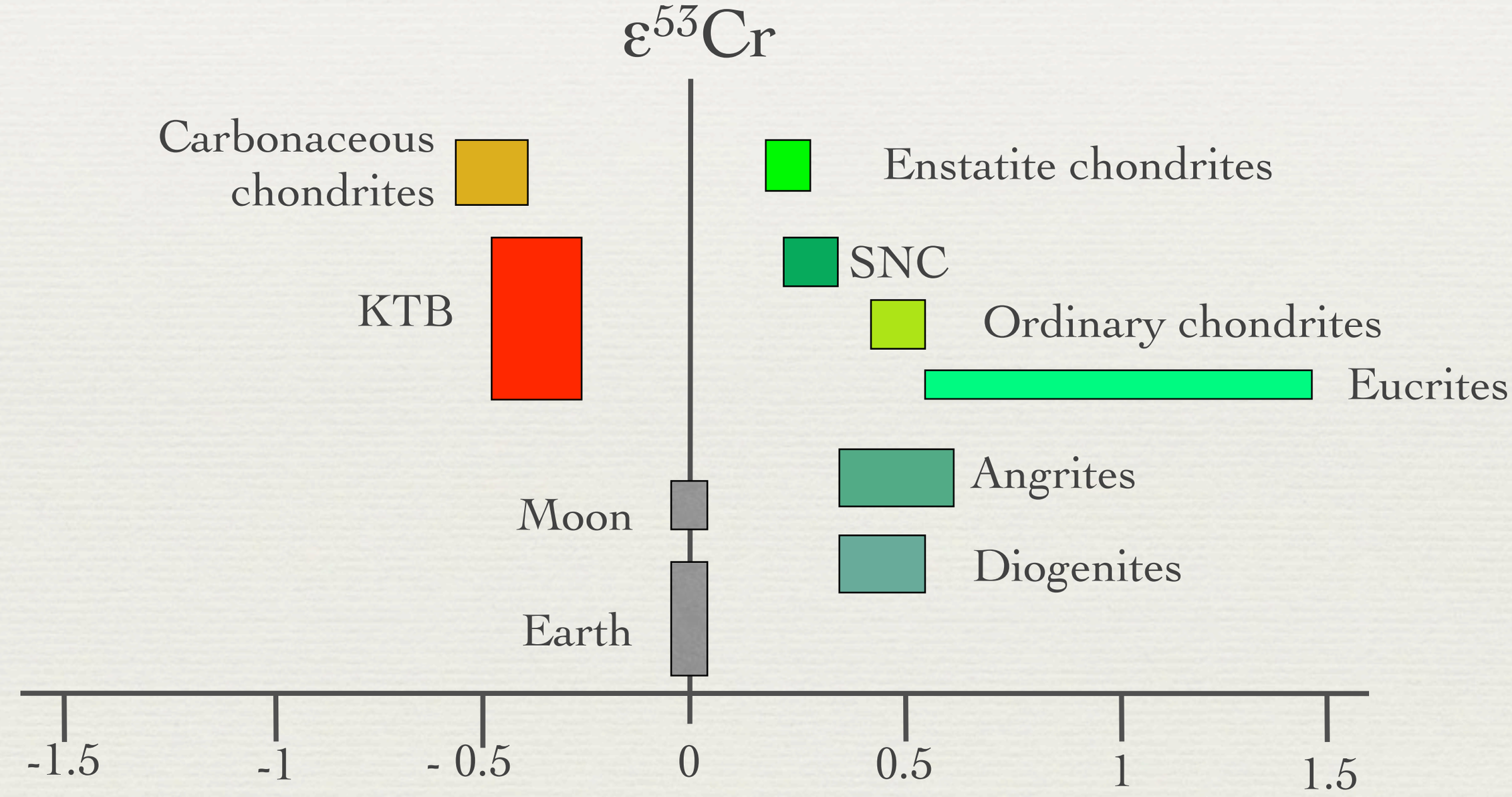

Clear distinction between carbonaceous & other meteorites

Name	Country	Diameter (km)	Location (center)	Bolide type	Evidence	References
Wabar	Saudia Arabia	0.10[a]	21°30′N, 50°28′E	IIIAB iron	M, S	Morgan *et al.* (1975), Mittlefehldt *et al.* (1992b)
Kaalijärvi	Estonia	0.11[a]	58°24′N, 22°40′E	IAB	M	Buchwald (1975)
Henbury	Australia	0.16[a]	24°35′S, 133°09′E	IIIAB	M, S	Taylor (1967)
Odessa	USA	0.17[a]	31°45′N, 102°29′W	IIIAB	M	Buchwald (1975)
Boxhole	Australia	0.17	22°37′S, 135°12′E	IIIAB	M	Buchwald (1975)
Macha	Russia	0.3[a]	59°59′N, 118°00′E	Iron	MS	Gurov (1996)
Aouelloul	Mauritania	0.4	20°15′N, 12°41′W	Iron (IIIB, IIID?)	S, Os	Morgan *et al.* (1975), Koeberl *et al.* (1998)
Monturaqui	Chile	0.46	23°56′S, 68°17′W	IAB	M, S	Bunch and Cassidy (1972), Buchwald (1975)
Kalkkop	South Africa	0.64	32°42′S, 24°26′E	Chondrite?	S, Os	Koeberl *et al.* (1994a), Reimold *et al.* (1998)
Wolfe Creek	Australia	0.9	19°18′S, 127°46′E	IIIAB	M, S	Attrep *et al.* (1991)
Meteor (Barringer)	USA	1.2	35°02′N, 111°01′W	IAB	M, S	Morgan *et al.* (1975), Mittlefehldt *et al.* (1992a)
Saltpan	South Africa	1.2	25°24′S, 28°05′E	Chondrite	S, Os	Koeberl *et al.* (1994a)
Roter Kamm	Namibia	2.5	27°46′S, 16°18′E	Chondrite?	S	Reimold *et al.* (unpublished data
New Quebec	Canada	3.4	61°17′N, 73°40′W	Chondrite (L?)	S	Grieve *et al.* (1991) >, Evans *et al.* (1993)
Brent	Canada	3.8	46°05′N, 78°29′W	Chondrite	S	Palme *et al.* (1981), Evans *et al.* (1993)
Gow Lake	Canada	4	56°27′N, 104°29′W	Iron?	(S)	Wolf *et al.* (1980)
Rio Cuarto	Argentina	4.5[a]	30°52′S, 64°14′W	Chondrite (H)	M, S, Os	Schultz *et al.* (1994), Koeberl (unpublished data)
Ilyinets	Ukraine	4.5	49°06′N, 29°12′E	Iron?	S	Grieve and Shoemaker (1994)
Sääksjärvi	Finland	5	61°24′N, 22°24′E	Stony-iron, iron?	S	Palme *et al.* (1980), Schmidt *et al.* (1997)
Gardnos	Norway	6	60°40′N, 09°00′E	Chondrite	S, Os	French *et al.* (1997)
Wanapitei	Canada	7.5	46°45′N, 80°45′W	Chondrite	S	Wolf *et al.* (1980), Evans *et al.* (1993)
Mien	Sweden	9	56°25′N, 14°52′E	Stone?	S	Palme *et al.* (1980)
Bosumtwi	Ghana	11	06°30′N, 01°25′W	L Chondrite	S, Os, Cr	Koeberl and Shirey (1993), Koeberl *et al.* (2004)
Ternovka	Ukraine	12	48°01′N, 33°05′E	Chondrite?	S	Grieve and Shoemaker (1994)
Nicholson Lake	Canada	12.5	62°40′N, 102°41′W	Achondrite	S	Wolf *et al.* (1980)
Zhamanshin	Kazakhstan	13.5	48°20′N, 60°58′E	Chondrite (Iron?)	S	Glass *et al.* (1983), Palme *et al.* (1978)
Dellen	Sweden	15	61°55′N, 16°39′E	Stone?	S	Palme *et al.* (1980)
Obolon	Ukraine	15	49°30′N, 32°55′E	Iron?	S	Grieve and Shoemaker (1994)
Lappajärvi	Finland	17	63°12′N, 23°42′E	Chondrite	S	Göbel *et al.* (1980)
Elgygytgyn	Russia	18	67°30′N, 172°00′E	Achondrite?	S	Grieve and Shoemaker (1994)
Clearwater East	Canada	22	56°05′N, 74°07′W	L Chondrite	S, Cr	McDonald (2002); Shukolyukov and Lugmair (2000)
Rochechouart	France	23	45°50′N, 00°56′E	Chondrite? Iron?	S, Cr	Janssens *et al.* (1977), Wolf *et al.* (1980), Lambert (1982), Shukolyukov and Lugmair (2000)
Ries	Germany	24	48°53′N, 10°37′E	Achondrite?	S	Morgan *et al.* (1979), Schmidt and Pernicka (1994)
Boltysh	Ukraine	25	48°45′N, 32°10′E	Chondrite?	S	Grieve and Shoemaker (1994)
Strangways	Australia	25	15°12′S, 133°35′E	Achondrite	S	Morgan and Wandless (1983)
Mistastin	Canada	28	55°53′N, 63°18′W	Iron?	S	Wolf *et al.* (1980)
Manson	USA	38	42°35′N, 94°33′W	Chondrite	S, Os	Pernicka *et al.* (1996), Koeberl and Shirey (1996)
Mjølnir	Norway	40	73°48′N, 29°40′E	Iron	S	Dypvik and Attrep (1999)
Morokweng	USA	70	26°20′S, 23°32′E	L Chondrite	S, Os, Cr	Koeberl *et al.* (1997a, 2002b), McDonald *et al.* (2001), Koeberl and Reimold (2003)
Chesapeake Bay	USA	85	37°16′N, 76°01′W	Chondrite?	S, Os	Lee *et al.* (2006)
Acraman	Australia	90	32°01′S, 135°27′E	Chondrite	Es	Gostin *et al.* (1989), Wallace *et al.* (1990)
Kara	Russia	65–100	69°12′N, 65°00′E	Chondrite?	S	Nazarov *et al.* (1989, 1990)
Popigai	Russia	100	71°30′N, 111°00′E	L Chondrite	S	Masaitis and Raikhlin (1985), Masaitis (1994), Tagle and Claeys (2004)
Chicxulub	Mexico	180	21°20′N, 89°30′W	CM2 Chondrite	S, Os, Es, Cr	Koeberl *et al.* (1994b), Schuraytz *et al.* (1996), Shukolyukov and Lugmair (1998), Trinquier *et al.* (2006)
Vredefort	South Africa	300	27°00′S, 27°30′E	Chondrite	S, Os	Koeberl *et al.* (1996b)

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Monturaqui	Chile	0.46	23°56′S, 68°17′W	IAB	M, S	Bunch and Cassidy (1972), Buchwald (1975)
Kalkkop	South Africa	0.64	32°42′S, 24°26′E	Chondrite?	S, Os	Koeberl *et al.* (1994a), Reimold *et al.* (1998)
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Saltpan	South Africa	1.2	25°24′S, 28°05′E	Chondrite	S, Os	Koeberl *et al.* (1994a)
Roter Kamm	Namibia	2.5	27°46′S, 16°18′E	Chondrite?	S	Reimold *et al.* (unpublished data
New Quebec	Canada	3.4	61°17′N, 73°40′W	Chondrite (L?)	S	Grieve *et al.* (1991) >, Evans *et al.* (1993)
Brent	Canada	3.8	46°05′N, 78°29′W	Chondrite	S	Palme *et al.* (1981), Evans *et al.* (1993)
Gow Lake	Canada	4	56°27′N, 104°29′W	Iron?	(S)	Wolf *et al.* (1980)
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Koeberl 2007

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Odessa	USA	0.17[a]	31°45′N, 102°29′W	IIIAB	M	Buchwald (1975)
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Rio Cuarto	Argentina	4.5[a]	30°52′S, 64°14′W	Chondrite (H)	M, S, Os	Schultz *et al.* (1994), Koeberl (unpublished data)
Ilyinets	Ukraine	4.5	49°06′N, 29°12′E	Iron?	S	Grieve and Shoemaker (1994)
Sääksjärvi	Finland	5	61°24′N, 22°24′E	Stony-iron, iron?	S	Palme *et al.* (1980), Schmidt *et al.* (1997)
Gardnos	Norway	6	60°40′N, 09°00′E	Chondrite	S, Os	French *et al.* (1997)
Wanapitei	Canada	7.5	46°45′N, 80°45′W	Chondrite	S	Wolf *et al.* (1980), Evans *et al.* (1993)
Mien	Sweden	9	56°25′N, 14°52′E	Stone?	S	Palme *et al.* (1980)
Bosumtwi	Ghana	11	06°30′N, 01°25′W	L Chondrite	S, Os, Cr	Koeberl and Shirey (1993), Koeberl *et al.* (2004)
Ternovka	Ukraine	12	48°01′N, 33°05′E	Chondrite?	S	Grieve and Shoemaker (1994)
Nicholson Lake	Canada	12.5	62°40′N, 102°41′W	Achondrite	S	Wolf *et al.* (1980)
Zhamanshin	Kazakhstan	13.5	48°20′N, 60°58′E	Chondrite (Iron?)	S	Glass *et al.* (1983), Palme *et al.* (1978)
Dellen	Sweden	15	61°55′N, 16°39′E	Stone?	S	Palme *et al.* (1980)
Obolon	Ukraine	15	49°30′N, 32°55′E	Iron?	S	Grieve and Shoemaker (1994)
Lappajärvi	Finland	17	63°12′N, 23°42′E	Chondrite	S	Göbel *et al.* (1980)
Elgygytgyn	Russia	18	67°30′N, 172°00′E	Achondrite?	S	Grieve and Shoemaker (1994)
Clearwater East	Canada	22	56°05′N, 74°07′W	L Chondrite	S, Cr	McDonald (2002); Shukolyukov and Lugmair (2000)
Rochechouart	France	23	45°50′N, 00°56′E	Chondrite? Iron?	S, Cr	Janssens *et al.* (1977), Wolf *et al.* (1980), Lambert (1982), Shukolyukov and Lugmair (2000)
Ries	Germany	24	48°53′N, 10°37′E	Achondrite?	S	Morgan *et al.* (1979), Schmidt and Pernicka (1994)
Boltysh	Ukraine	25	48°45′N, 32°10′E	Chondrite?	S	Grieve and Shoemaker (1994)
Strangways	Australia	25	15°12′S, 133°35′E	Achondrite	S	Morgan and Wandless (1983)
Mistastin	Canada	28	55°53′N, 63°18′W	Iron?	S	Wolf *et al.* (1980)
Manson	USA	38	42°35′N, 94°33′W	Chondrite	S, Os	Pernicka *et al.* (1996), Koeberl and Shirey (1996)
Mjølnir	Norway	40	73°48′N, 29°40′E	Iron	S	Dypvik and Attrep (1999)
Morokweng	USA	70	26°20′S, 23°32′E	L Chondrite	S, Os, Cr	Koeberl *et al.* (1997a, 2002b), McDonald *et al.* (2001), Koeberl and Reimold (2003)
Chesapeake Bay	USA	85	37°16′N, 76°01′W	Chondrite?	S, Os	Lee *et al.* (2006)
Acraman	Australia	90	32°01′S, 135°27′E	Chondrite	Es	Gostin *et al.* (1989), Wallace *et al.* (1990)
Kara	Russia	65–100	69°12′N, 65°00′E	Chondrite?	S	Nazarov *et al.* (1989, 1990)
Popigai	Russia	100	71°30′N, 111°00′E	L Chondrite	S	Masaitis and Raikhlin (1985), Masaitis (1994), Tagle and Claeys (2004)
Chicxulub	Mexico	180	21°20′N, 89°30′W	CM2 Chondrite	S, Os, Es, Cr	Koeberl *et al.* (1994b), Schuraytz *et al.* (1996), Shukolyukov and Lugmair (1998), Trinquier *et al.* (2006)
Vredefort	South Africa	300	27°00′S, 27°30′E	Chondrite	S, Os	Koeberl *et al.* (1996b)

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Name	Country	Diameter (km)	Location (center)	Bolide type	Evidence	References
Wabar	Saudia Arabia	0.10[a]	21°30′N, 50°28′E	IIIAB iron	M, S	Morgan *et al.* (1975), Mittlefehldt *et al.* (1992b)
Kaalijärvi	Estonia	0.11[a]	58°24′N, 22°40′E	IAB	M	Buchwald (1975)
Henbury	Australia	0.16[a]	24°35′S, 133°09′E	IIIAB	M, S	Taylor (1967)
Odessa	USA	0.17[a]	31°45′N, 102°29′W	IIIAB	M	Buchwald (1975)
Boxhole	Australia	0.17	22°37′S, 135°12′E	IIIAB	M	Buchwald (1975)
Macha	Russia	0.3[a]	59°59′N, 118°00′E	Iron	MS	Gurov (1996)
Aouelloul	Mauritania	0.4	20°15′N, 12°41′W	Iron (IIIB, IIID?)	S, Os	Morgan *et al.* (1975), Koeberl *et al.* (1998)
Monturaqui	Chile	0.46	23°56′S, 68°17′W	IAB	M, S	Bunch and Cassidy (1972), Buchwald (1975)
Kalkkop	South Africa	0.64	32°42′S, 24°26′E	Chondrite?	S, Os	Koeberl *et al.* (1994a), Reimold *et al.* (1998)
Wolfe Creek	Australia	0.9	19°18′S, 127°46′E	IIIAB	M, S	Attrep *et al.* (1991)
Meteor (Barringer)	USA	1.2	35°02′N, 111°01′W	IAB	M, S	Morgan *et al.* (1975), Mittlefehldt *et al.* (1992a)
Saltpan	South Africa	1.2	25°24′S, 28°05′E	Chondrite	S, Os	Koeberl *et al.* (1994a)
Roter Kamm	Namibia	2.5	27°46′S, 16°18′E	Chondrite?	S	Reimold *et al.* (unpublished data
New Quebec	Canada	3.4	61°17′N, 73°40′W	Chondrite (L?)	S	Grieve *et al.* (1991) >, Evans *et al.* (1993)
Brent	Canada	3.8	46°05′N, 78°29′W	Chondrite	S	Palme *et al.* (1981), Evans *et al.* (1993)
Gow Lake	Canada	4	56°27′N, 104°29′W	Iron?	(S)	Wolf *et al.* (1980)
Rio Cuarto	Argentina	4.5[a]	30°52′S, 64°14′W	Chondrite (H)	M, S, Os	Schultz *et al.* (1994), Koeberl (unpublished data)
Ilyinets	Ukraine	4.5	49°06′N, 29°12′E	Iron?	S	Grieve and Shoemaker (1994)
Sääksjärvi	Finland	5	61°24′N, 22°24′E	Stony-iron, iron?	S	Palme *et al.* (1980), Schmidt *et al.* (1997)
Gardnos	Norway	6	60°40′N, 09°00′E	Chondrite	S, Os	French *et al.* (1997)
Wanapitei	Canada	7.5	46°45′N, 80°45′W	Chondrite	S	Wolf *et al.* (1980), Evans *et al.* (1993)
Mien	Sweden	9	56°25′N, 14°52′E	Stone?	S	Palme *et al.* (1980)
Bosumtwi	Ghana	11	06°30′N, 01°25′W	L Chondrite	S, Os, Cr	Koeberl and Shirey (1993), Koeberl *et al.* (2004)
Ternovka	Ukraine	12	48°01′N, 33°05′E	Chondrite?	S	Grieve and Shoemaker (1994)
Nicholson Lake	Canada	12.5	62°40′N, 102°41′W	Achondrite	S	Wolf *et al.* (1980)
Zhamanshin	Kazakhstan	13.5	48°20′N, 60°58′E	Chondrite (Iron?)	S	Glass *et al.* (1983), Palme *et al.* (1978)
Dellen	Sweden	15	61°55′N, 16°39′E	Stone?	S	Palme *et al.* (1980)
Obolon	Ukraine	15	49°30′N, 32°55′E	Iron?	S	Grieve and Shoemaker (1994)
Lappajärvi	Finland	17	63°12′N, 23°42′E	Chondrite	S	Göbel *et al.* (1980)
Elgygytgyn	Russia	18	67°30′N, 172°00′E	Achondrite?	S	Grieve and Shoemaker (1994)
Clearwater East	Canada	22	56°05′N, 74°07′W	L Chondrite	S, Cr	McDonald (2002); Shukolyukov and Lugmair (2000)
Rochechouart	France	23	45°50′N, 00°56′E	Chondrite? Iron?	S, Cr	Janssens *et al.* (1977), Wolf *et al.* (1980), Lambert (1982), Shukolyukov and Lugmair (2000)
Ries	Germany	24	48°53′N, 10°37′E	Achondrite?	S	Morgan *et al.* (1979), Schmidt and Pernicka (1994)
Boltysh	Ukraine	25	48°45′N, 32°10′E	Chondrite?	S	Grieve and Shoemaker (1994)
Strangways	Australia	25	15°12′S, 133°35′E	Achondrite	S	Morgan and Wandless (1983)
Mistastin	Canada	28	55°53′N, 63°18′W	Iron?	S	Wolf *et al.* (1980)
Manson	USA	38	42°35′N, 94°33′W	Chondrite	S, Os	Pernicka *et al.* (1996), Koeberl and Shirey (1996)
Mjølnir	Norway	40	73°48′N, 29°40′E	Iron	S	Dypvik and Attrep (1999)
Morokweng	USA	70	26°20′S, 23°32′E	L Chondrite	S, Os, Cr	Koeberl *et al.* (1997a, 2002b), McDonald *et al.* (2001), Koeberl and Reimold (2003)
Chesapeake Bay	USA	85	37°16′N, 76°01′W	Chondrite?	S, Os	Lee *et al.* (2006)
Acraman	Australia	90	32°01′S, 135°27′E	Chondrite	Es	Gostin *et al.* (1989), Wallace *et al.* (1990)
Kara	Russia	65–100	69°12′N, 65°00′E	Chondrite?	S	Nazarov *et al.* (1989, 1990)
Popigai	Russia	100	71°30′N, 111°00′E	L Chondrite	S	Masaitis and Raikhlin (1985), Masaitis (1994), Tagle and Claeys (2004)
Chicxulub	Mexico	180	21°20′N, 89°30′W	CM2 Chondrite	S, Os, Es, Cr	Koeberl *et al.* (1994b), Schuraytz *et al.* (1996), Shukolyukov and Lugmair (1998), Trinquier *et al.* (2006)
Vredefort	South Africa	300	27°00′S, 27°30′E	Chondrite	S, Os	Koeberl *et al.* (1996b)

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Os isotopes already been done

Table 5. RE-OS abundances and isotopic compositions of Gardnos rocks.

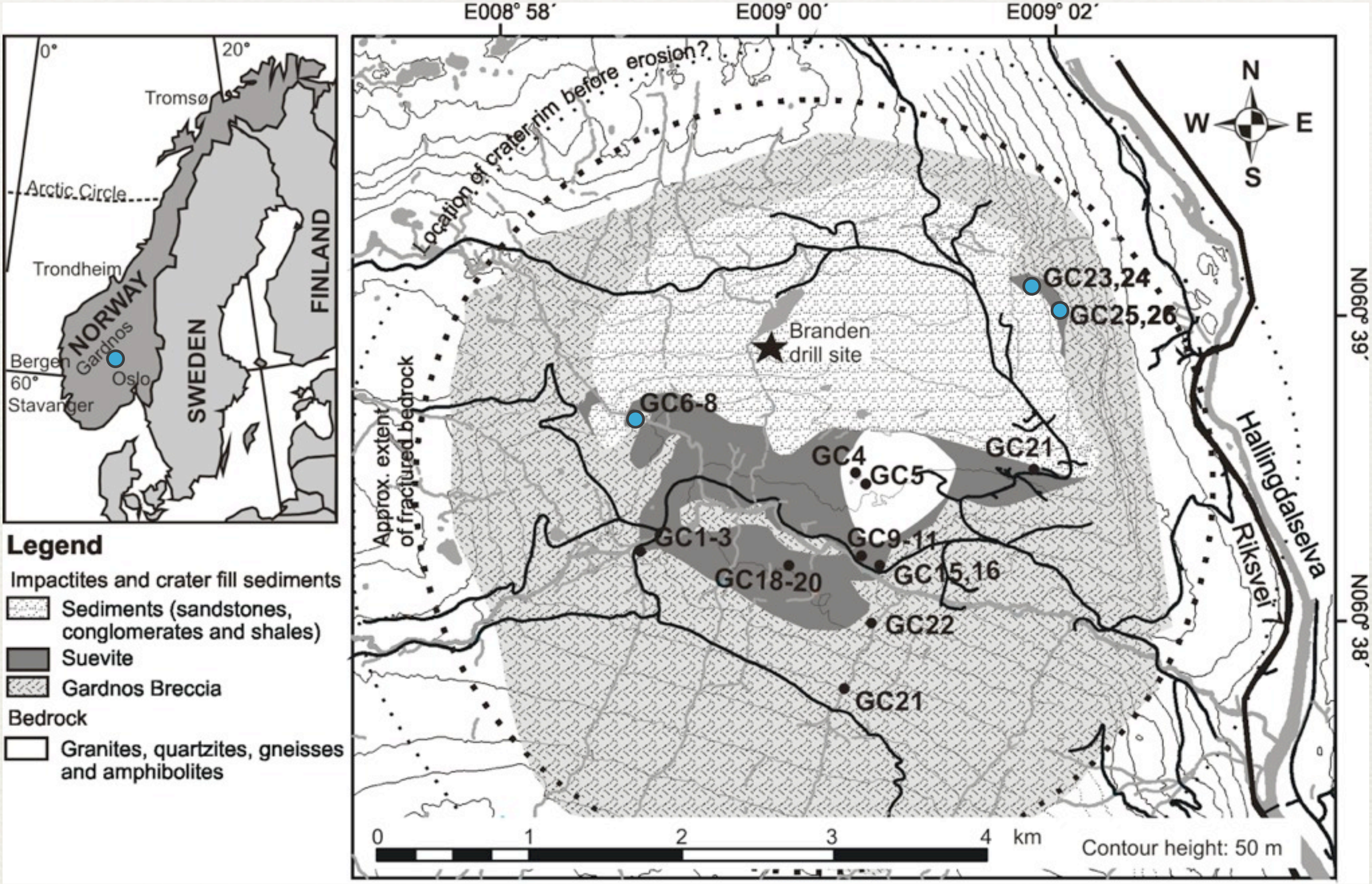
Sample	Re (ppb)	^{188}Os	Os (ppb)	^{187}Os (%)	$^{187}Re/^{188}Os$	$^{187}Os/^{188}Os$	$(^{187}Os/^{188}Os)_{650Ma}$
Target rocks							
NG-94-2 (Amphibolite)	2.36	18.2	0.0346	26.0	435.2	2.605	−2.06
NG-94-11 (Gneiss)	0.0029	2.34	0.0035	4.62	4.17	0.363	0.32
NG-94-12 (Gneiss)	0.0063	3.71	0.0058	9.40	5.713	0.777	0.72
Melt-matrix breccias							
NG-94-30	0.770	476	0.683	1.87	5.437	0.141	0.083
(−12% Amphibolite)	0.48				3.442		0.104
(−20% Amphibolite)	0.30				2.107		0.118
NG-99	1.98	231	0.332	1.82	30.17	0.137	−0.19
(−12% Amphibolite)	1.69				24.61		−0.127
(−20% Amphibolite)	1.51				21.86		−0.097

French et al. 1997

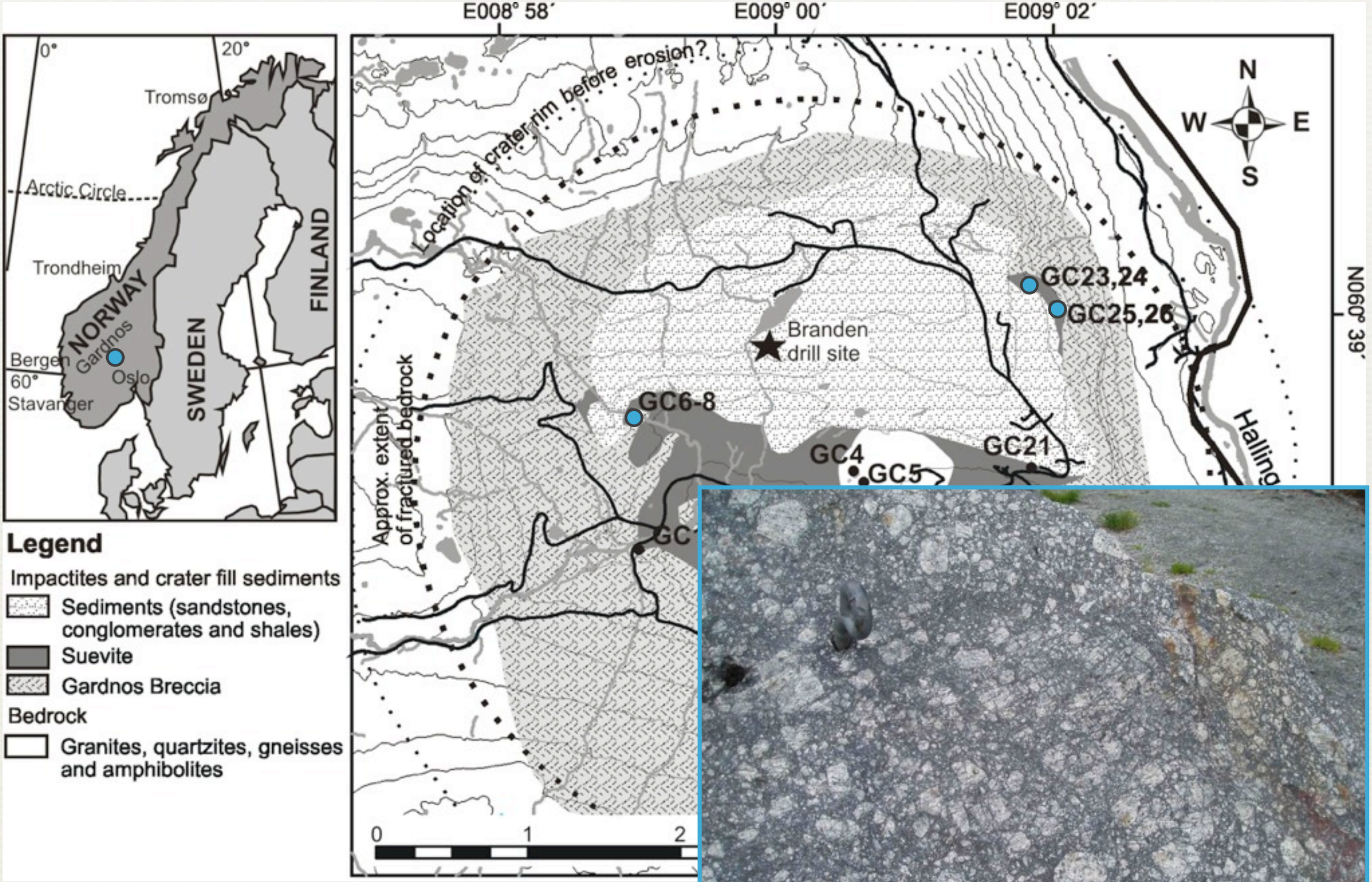
compared to $^{187}Os/^{188}Os$ 0.11-0.18 for chondrites and iron meteorites (e.g., Smoliar et al. 1996; Koeberl et al. 2002)

Possible amphibolitic contribution?

+ avg. Ir content of 1.3 ± 0.4 ng/g in suevites



Location of sampled sites at Gardnos, and distribution of target and impactite lithologies, modified after Kalleson et al. 2008



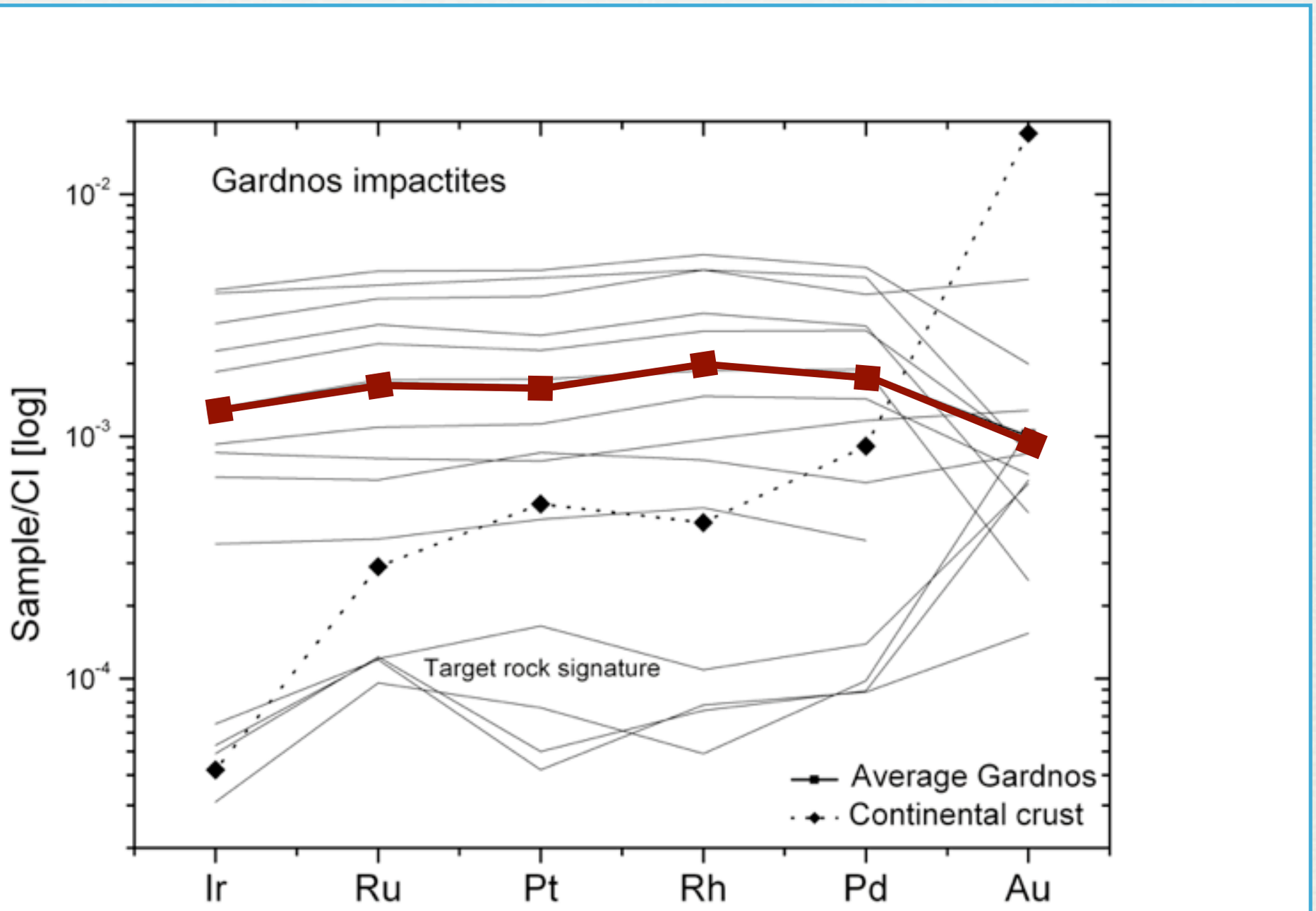
Location of sampled sites at Gardnos, a
lithologies, modified afte

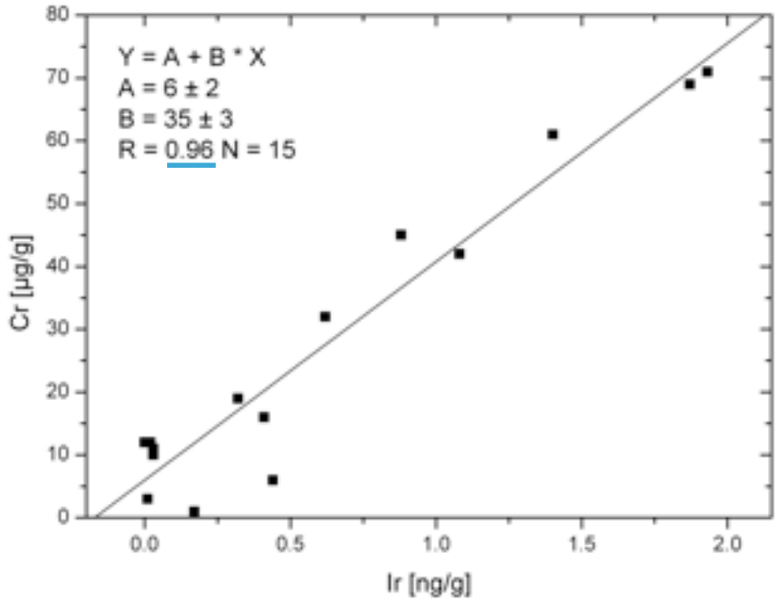
Gardnos Breccia

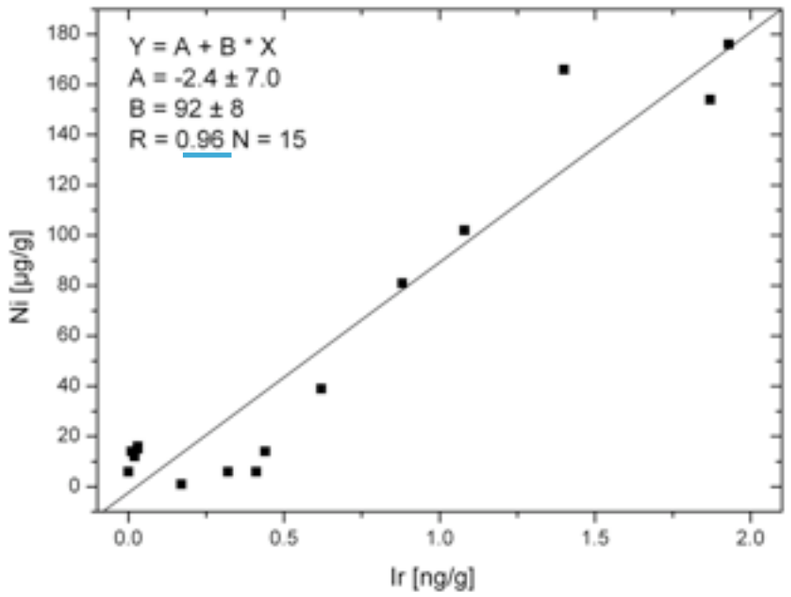
Location of sampled sites at Gardnos, a
lithologies, modified aft

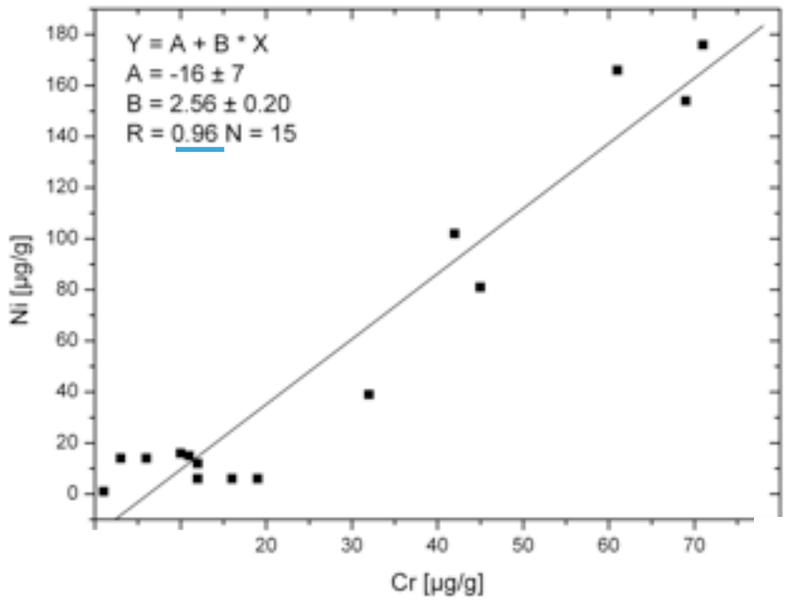
15 samples were analyzed for major, trace, and PGE content

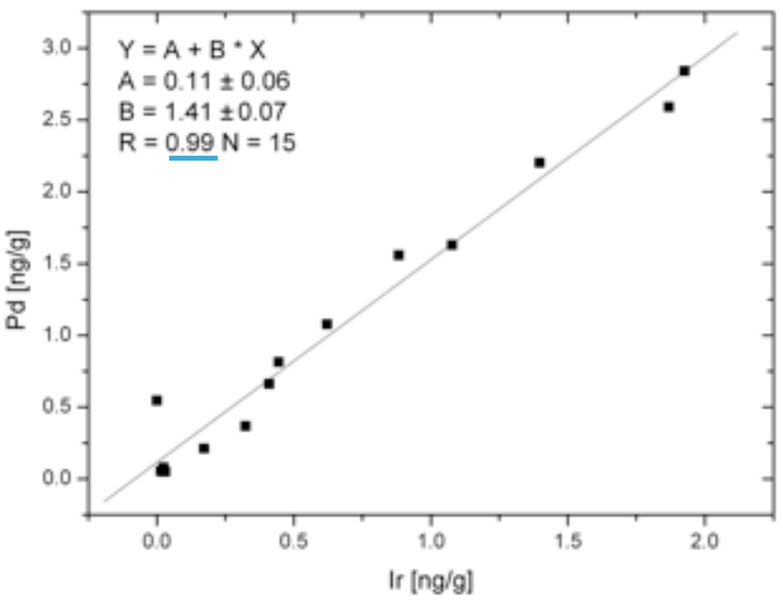
Large variations in Ni (1–176 µg/g), Cr (1–71 µg/g), and Ir (bdl-1.926 ng/g) contents.
Highest PGE at boundary between suevites and overlying post-impact sedimentary infill.

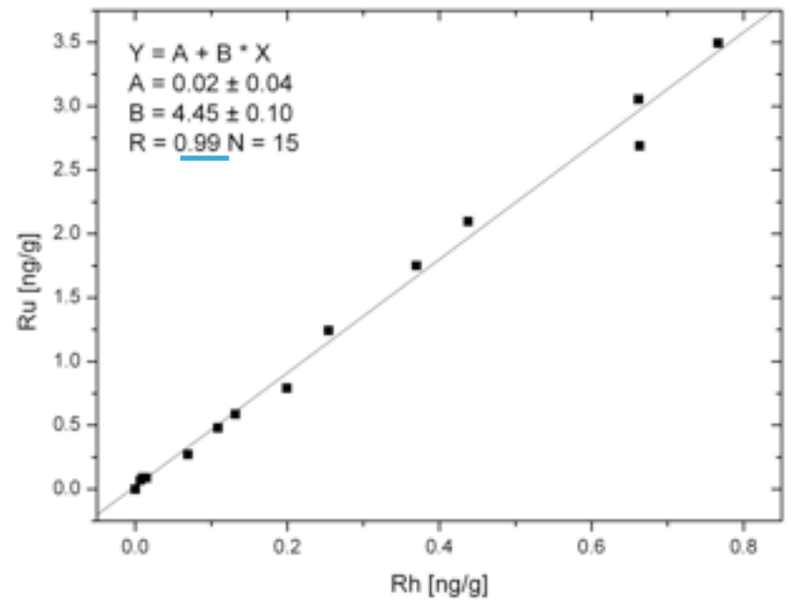



Y = A + B * X
A = 6 ± 2
B = 35 ± 3
R = 0.96 N = 15
Cr [µg/g]
Ir [ng/g]

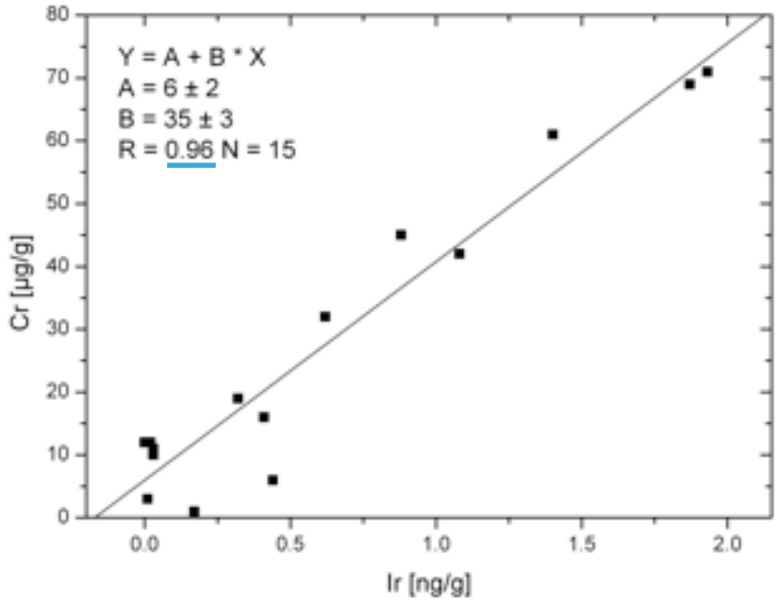

Y = A + B * X
A = -2.4 ± 7.0
B = 92 ± 8
R = 0.96 N = 15
Ni [ng/g]
Ir [ng/g]

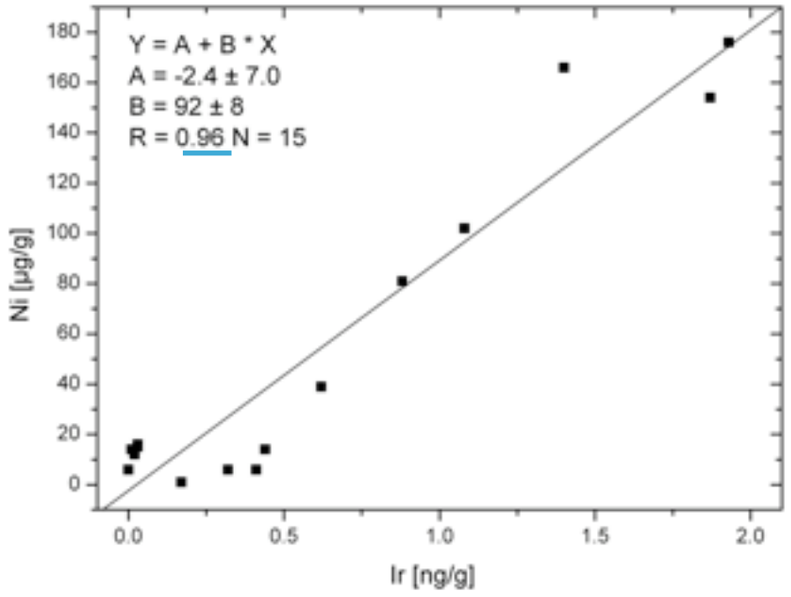

Y = A + B * X
A = -16 ± 7
B = 2.56 ± 0.20
R = 0.96 N = 15
Ni [ng/g]
Cr [µg/g]

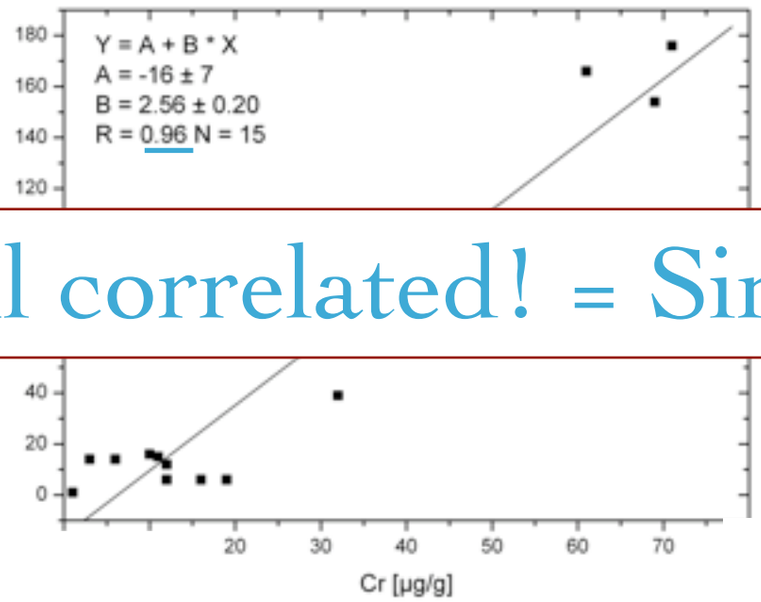

Y = A + B * X
A = 0.11 ± 0.06
B = 1.41 ± 0.07
R = 0.99 N = 15
Pd [ng/g]
Ir [ng/g]

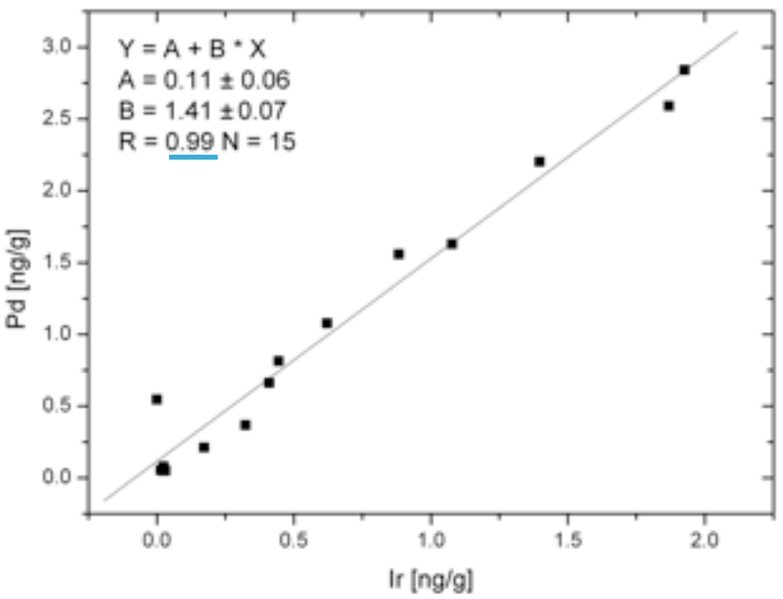

Y = A + B * X
A = 0.02 ± 0.04
B = 4.45 ± 0.10
R = 0.99 N = 15
Ru [ng/g]
Rh [ng/g]

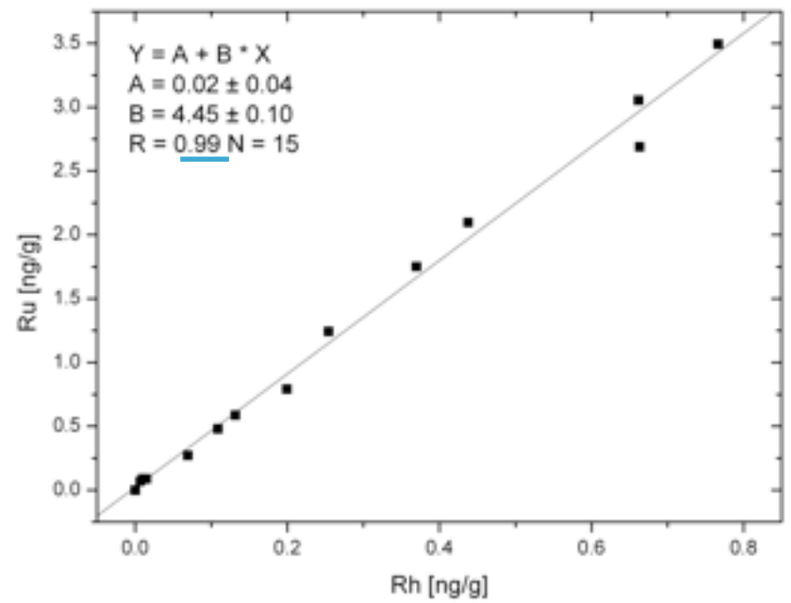
All extremely well correlated! = Single, common source

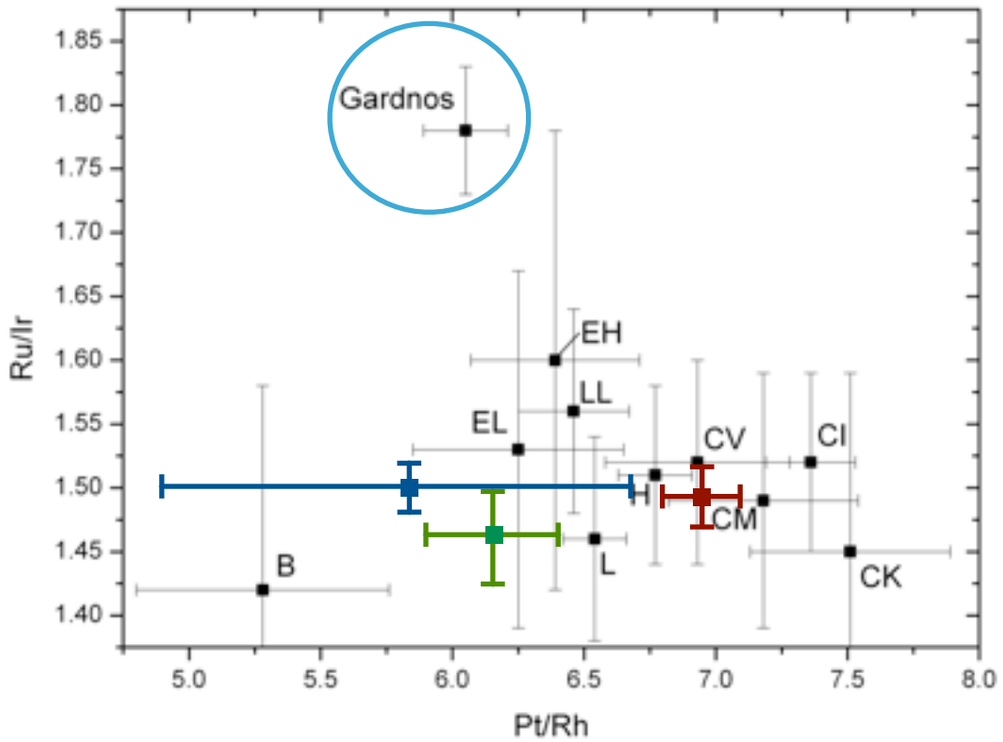










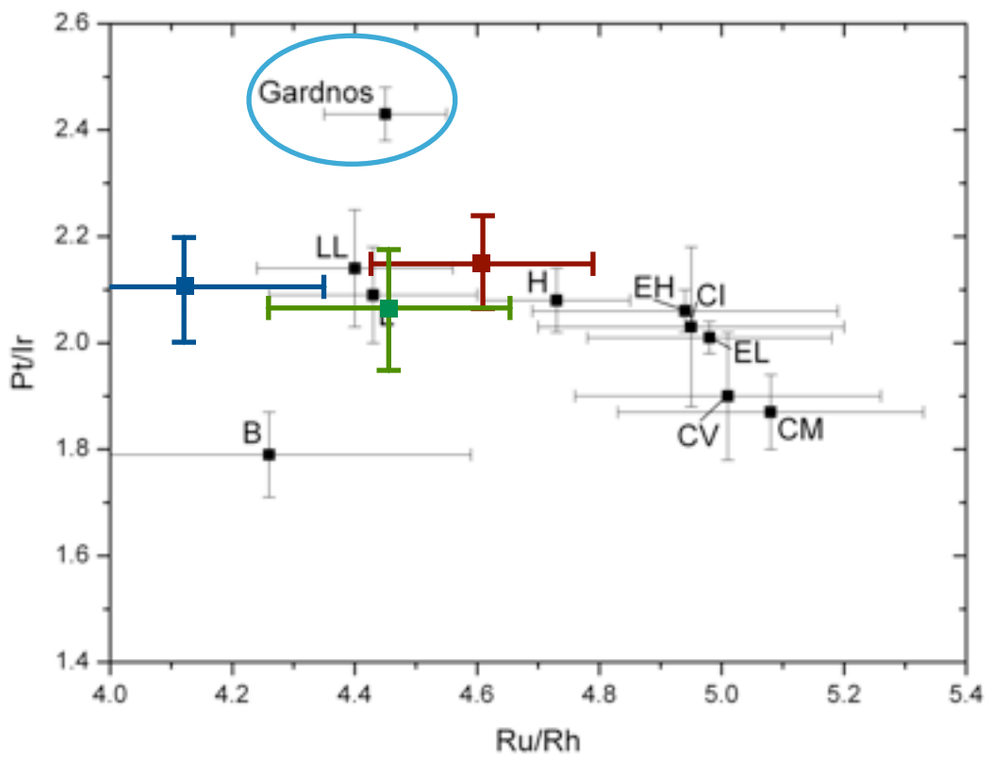


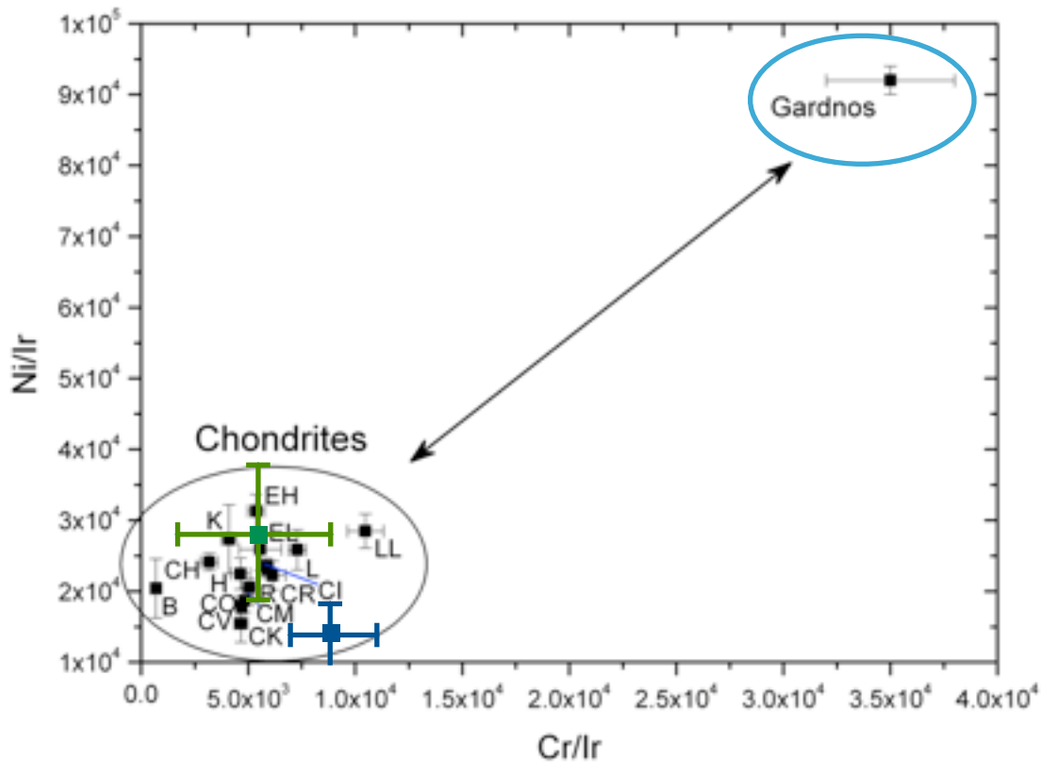
French et al. 1997 > chondrite?

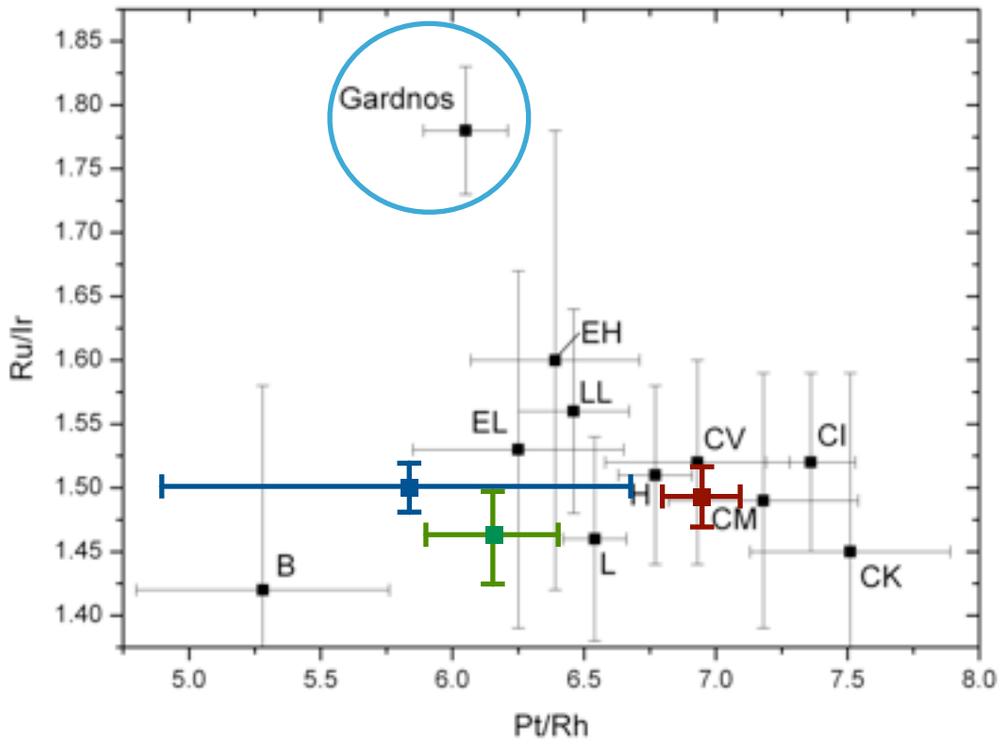
Compare to chondrites:

Morokweng, Popigai,

Lappajärvi







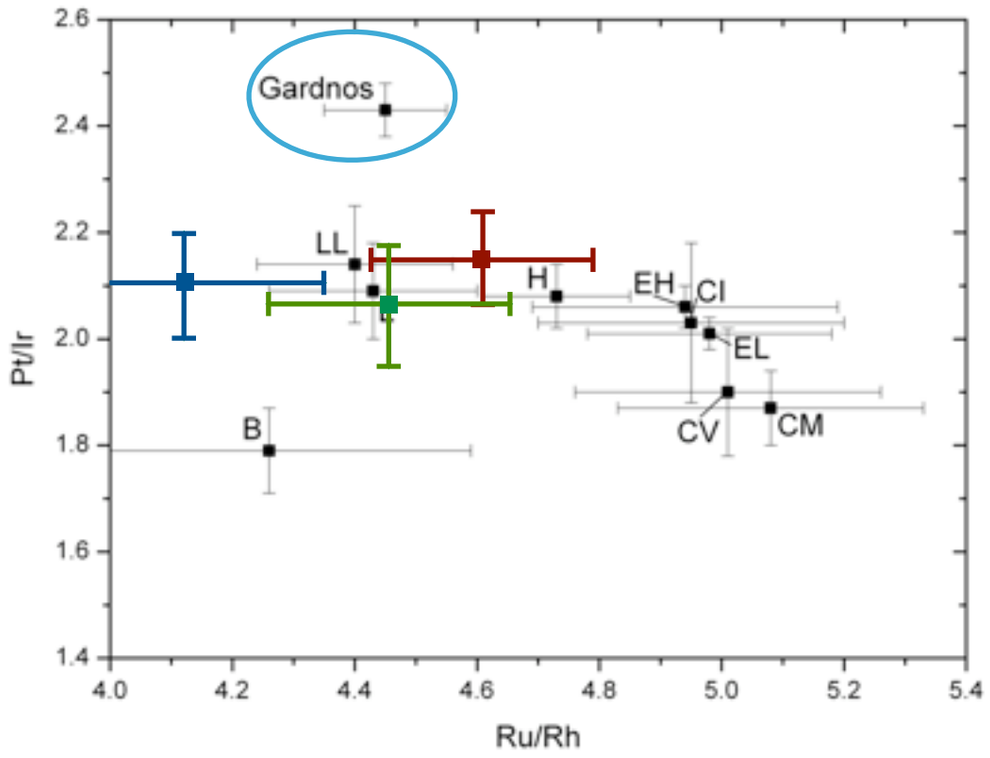
French et al. 1997 > chondrite?

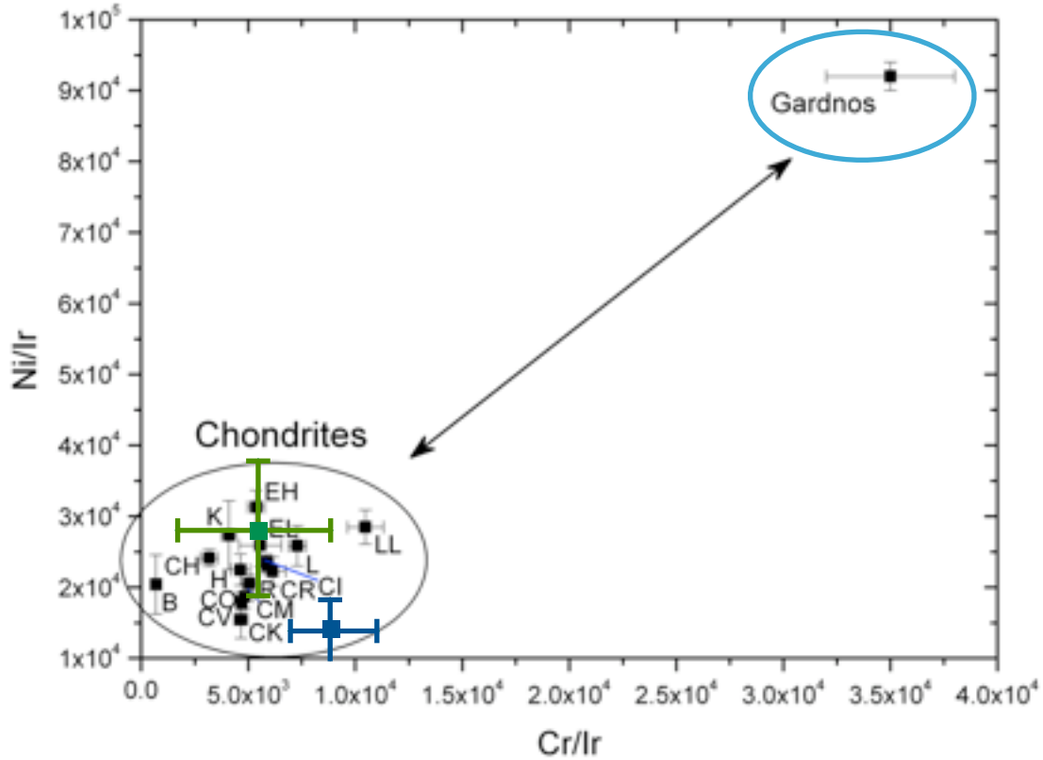
Compare to chondrites:

Morokweng, Popigai,

Lappajärvi

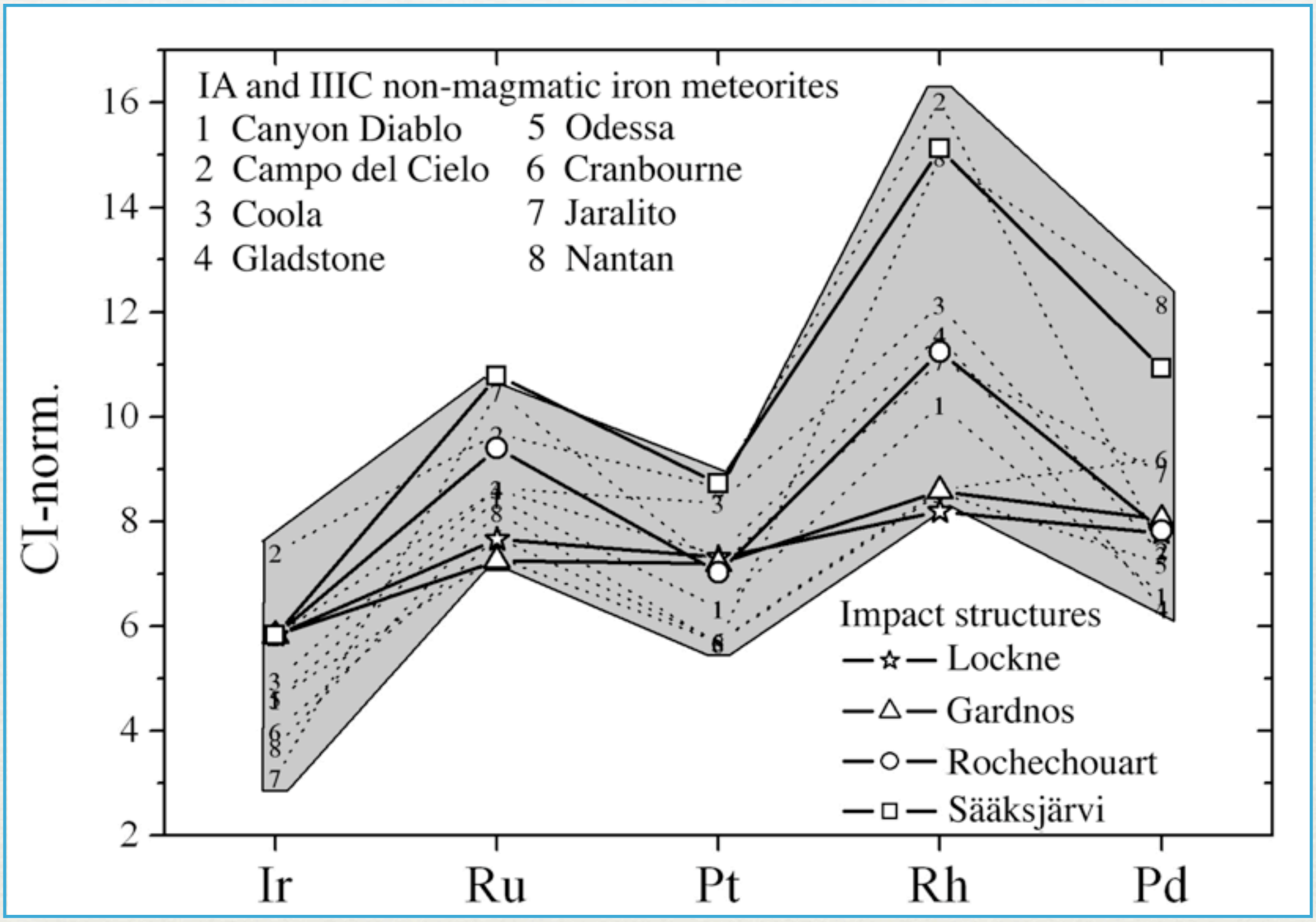
Close but no cigar!





Recently, different type of projectile has been ID'ed:

Non-magmatic iron (NMI) meteorites



What are NMI (IAB, IIICD, and IIE irons)?

IA Udei ~ 20 vol% silicates in iron matrix but can contain up to 90 vol% and more! (Mittlefehldt et al. 1998)

Second largest group of iron meteorites, including Canyon Diablo (Barringer Crater)

NMI are irons that underwent poorly understood processes

Break-up and reassembly of the same parent body

IAB irons + primitive winonaites = common parent body and link with the IIICD irons (e.g., Mittlefehldt et al. 1998).

H chondrites + silicate inclusions in IIE irons = similar bulk and mineral compositions, textures, and O-isotopic compositions (Olsen et al. 1994; Casanova et al. 1995)

Main mineral phases are olivine, pyroxene, and metal

= OC

= S-type asteroids?

However metallic iron has no characteristic absorption band and is hard to recognize from Earth (Burbine 2002)

Future plans: confirm + constrain metal/silicate ratio using Cr isotopes

Implications?

Gardnos was not formed by an ordinary chondrite, but by a related type of impactor, namely an 'iron'

Meteorites, asteroids, and impactors = mixture with a range in compositions + different genesis

>

Building blocks were all the same = chondritic

Larger structures (~ 5 km) also created by iron meteorites

Thank you!