Accuracy in quantitative phase analysis of complex mineral assemblages: A decade of Reynolds Cup round robins

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Outline

- The Reynolds Cup
- Sample Compositions
- Analytical techniques
- Quantitative analysis methods
- Summary
- Conclusions

The Reynolds Cup

- Biennial competition named after Bob Reynolds
- Established in 2000 by The Clay Minerals Society and sponsored by ChevronTexaco and the USGS
- Utilizes three sample mixtures of pure mineral phases that represent realistic sedimentary and weathered rock compositions
- Open to anyone interested in quantitative mineralogy using any available technique
- Commences early in the even numbered years
- Deadline approximately 1 month before the annual meeting of the CMS

The Reynolds Cup (cont)

- Entrants are judged on sample biases

$$TotalBias = \sum abs\left(W_{actual} - W_{submitted}\right)$$

- Top three with the lowest total bias are awarded with plaques and the winner receives the perpetual Reynolds Cup trophy
- Winner is invited to prepare samples for the next contest

Sample compositions

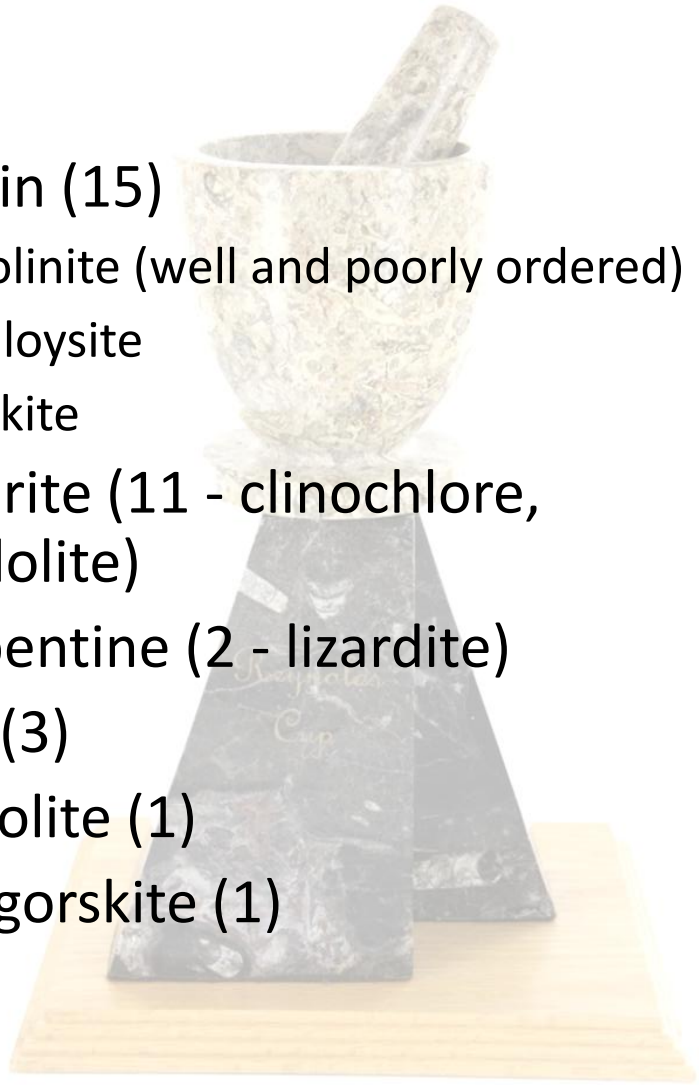
- Mudstone
- Sandstone
- Siltstone
- Calcareous mudstone
- Saline sedimentary rock
- Sediment from an evaporate environment
- Sample representing a hydrothermal alteration environment
- Soil formed on a parent material rich in ferromagnesian minerals and amorphous soil minerals
- Petroleum shale
- Nickel laterite
- Bauxite

Minerals used – non clays

- Quartz (18)
- K-feldspar (13)
- Plagioclase (14)
- Calcite (12)
- Dolomite (10)
- Magnesite (4)
- Aragonite (3)
- Huntite (1)
- Halite (6)
- Pyrite (7)
- Siderite (8)
- Barite (5)
- Gypsum (2)
- Anhydrite (2)
- Alunite (1)
- Hematite (6)
- Goethite (5)
- Magnetite (4)
- Anatase (9)
- Rutile (3)
- Ilmenite (3)
- Gibbsite (3)
- Bohmite (1)
- Fluorite (2)
- Apatite (1)
- Tourmaline (2)
- Zircon (2)
- Spinel (1)
- Opal-CT (1)
- Amphibole (3)
- Zeolite (1)
- Epidote (1)
- Birnessite (1)
- Arcanite (1)
- Amorphous (6)

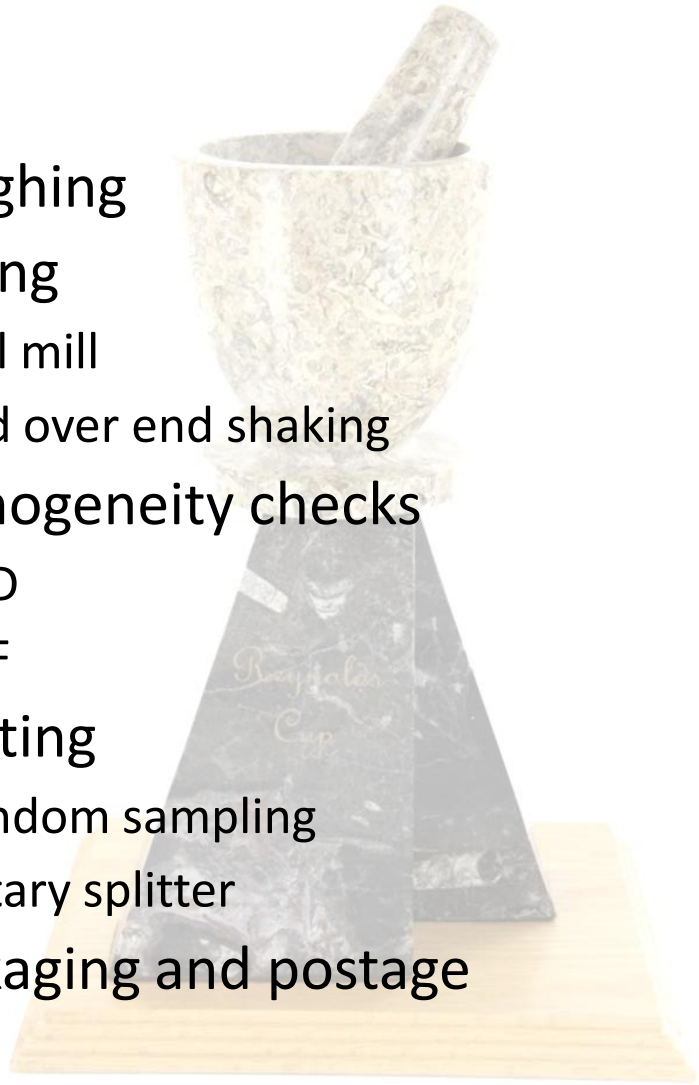
Minerals used – clays

- 2:1 Dioctahedral Clays (18)
  - Smectite (montmorillonite, nontronite)
  - Mixed layered (illite-smectite, glauconite-smectite)
  - Mica/Illite (muscovite $2M_1$, illite $1M_d$, 1M)
- 2:1 Trioctahedral Clays (6)
  - Smectite (saponite)
  - Vermiculite
  - Mixed layered (corrensite)
  - Mica (biotite)
- Kaolin (15)
  - Kaolinite (well and poorly ordered)
  - Halloysite
  - Dickite
- Chlorite (11 - clinochlore, ripidolite)
- Serpentine (2 - lizardite)
- Talc (3)
- Sepiolite (1)
- Palygorskite (1)

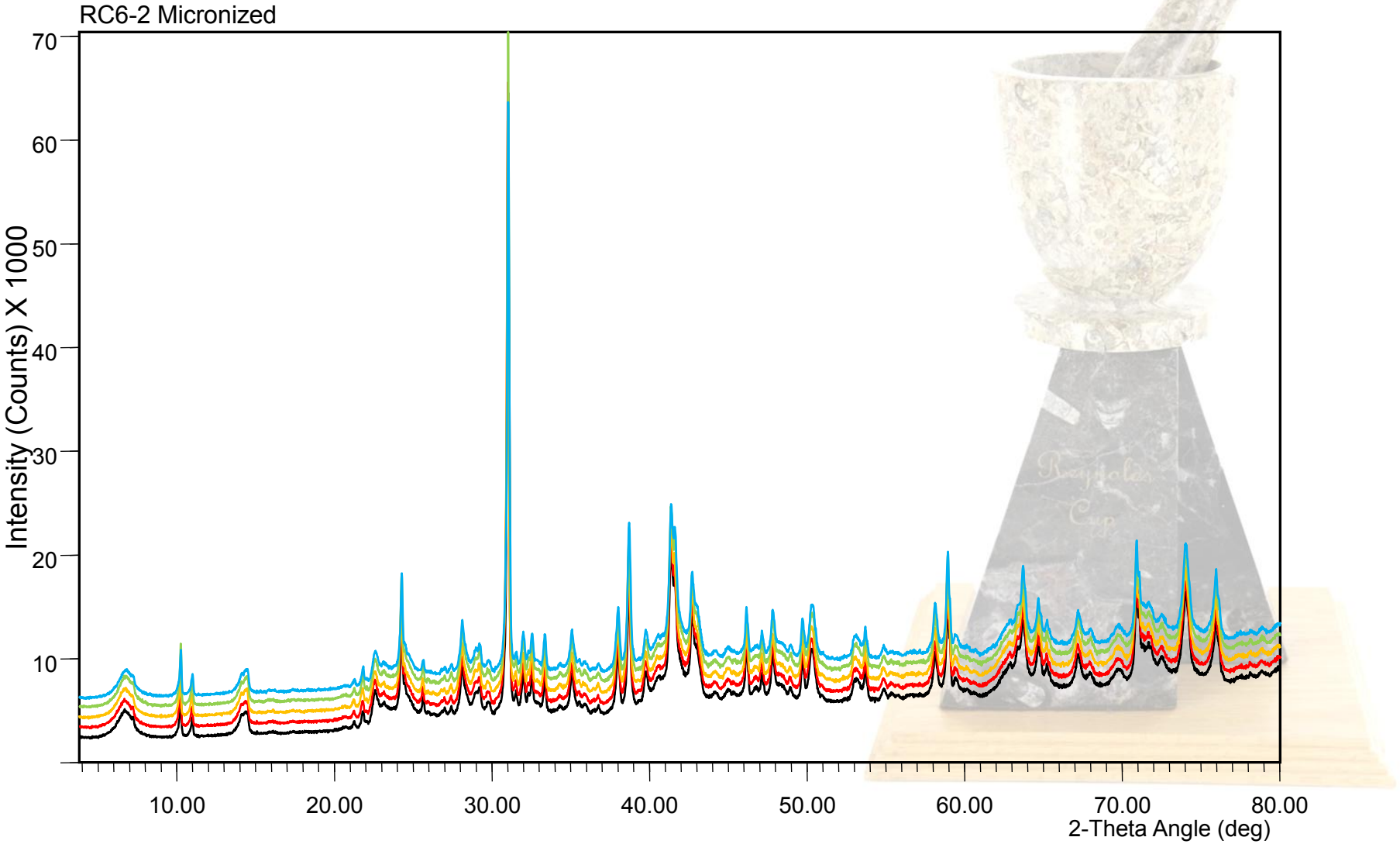


Sample preparation

- Purification
  - Hand picking
  - Sieving
  - Magnetic separation
  - Chemical treatments
  - Size fractionation (<2µm, <0.5µm, <0.2µm)
  - Synthesis
- Preparation
  - Grinding
  - Sieving (200-400µm)
  - Check for purity (XRD)
- Equilibrate
- Weighing
- Mixing
  - Ball mill
  - End over end shaking
- Homogeneity checks
  - XRD
  - XRF
- Splitting
  - Random sampling
  - Rotary splitter
- Packaging and postage

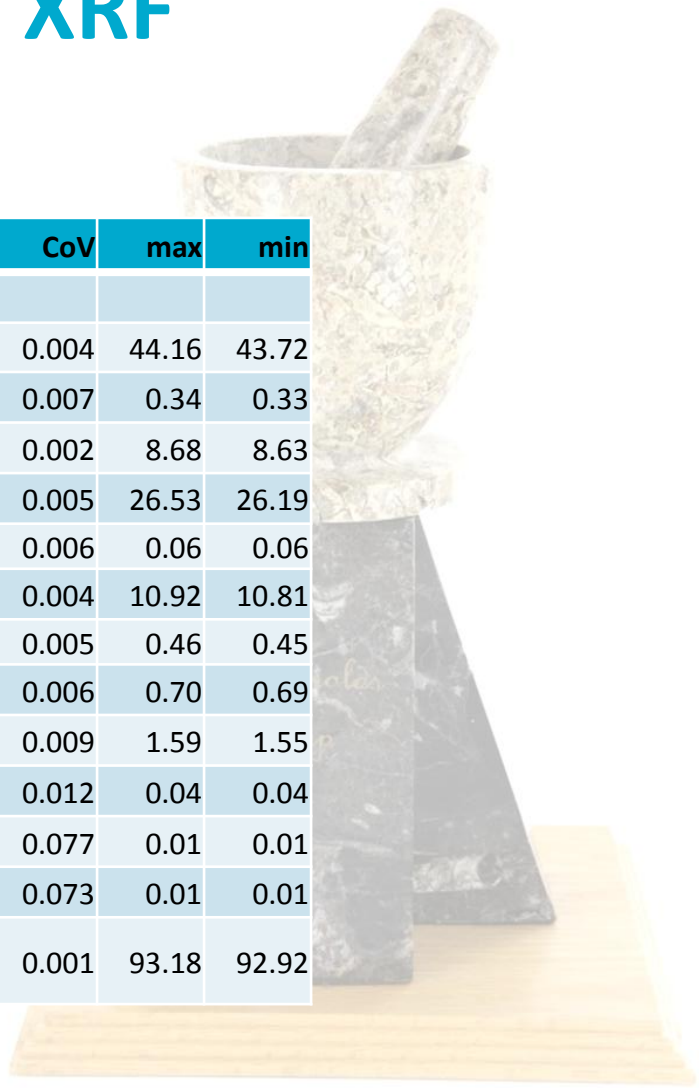


Homogeneity check RC6-2 - XRD



Homogeneity check RC6-2 - XRF

		2A	2B	2C	2D	2E		mean	stdev	CoV	max	min
SiO_2	(%)	43.81	44.16	43.72	44.10	43.97		43.95	0.19	0.004	44.16	43.72
TiO_2	(%)	0.34	0.34	0.33	0.34	0.34		0.34	0.00	0.007	0.34	0.33
Al_2O_3	(%)	8.68	8.67	8.64	8.64	8.63		8.65	0.02	0.002	8.68	8.63
Fe_2O_3	(%)	26.48	26.19	26.53	26.42	26.43		26.41	0.13	0.005	26.53	26.19
MnO	(%)	0.06	0.06	0.06	0.06	0.06		0.06	0.00	0.006	0.06	0.06
MgO	(%)	10.92	10.91	10.86	10.81	10.83		10.87	0.05	0.004	10.92	10.81
CaO	(%)	0.46	0.46	0.45	0.46	0.46		0.46	0.00	0.005	0.46	0.45
Na_2O	(%)	0.69	0.70	0.70	0.70	0.70		0.70	0.00	0.006	0.70	0.69
K_2O	(%)	1.55	1.58	1.56	1.59	1.57		1.57	0.01	0.009	1.59	1.55
P_2O_5	(%)	0.04	0.04	0.04	0.04	0.04		0.04	0.00	0.012	0.04	0.04
SO_3	(%)	0.01	0.01	0.01	0.01	0.01		0.01	0.00	0.077	0.01	0.01
Cl	(%)	0.01	0.01	0.01	0.01	0.01		0.01	0.00	0.073	0.01	0.01
Sum	(%)	93.05	93.13	92.92	93.18	93.04		93.06	0.10	0.001	93.18	92.92



Round robin statistics (2002-2012)

Year	Participants	Results Returned	Percentage Returned	Number of Mineral Phases
2002	40	15	37.5	36
2004	60	34	56.7	34
2006	64	37	57.8	42
2008	53	42	79.2	35
2010	76	63	82.9	42
2012	74	62	83.8	40
Total (mean)	367 (61.2)	253 (42.3)	(68.9)	229 (38.1)

Reynolds Cup Winners (2002-2012)

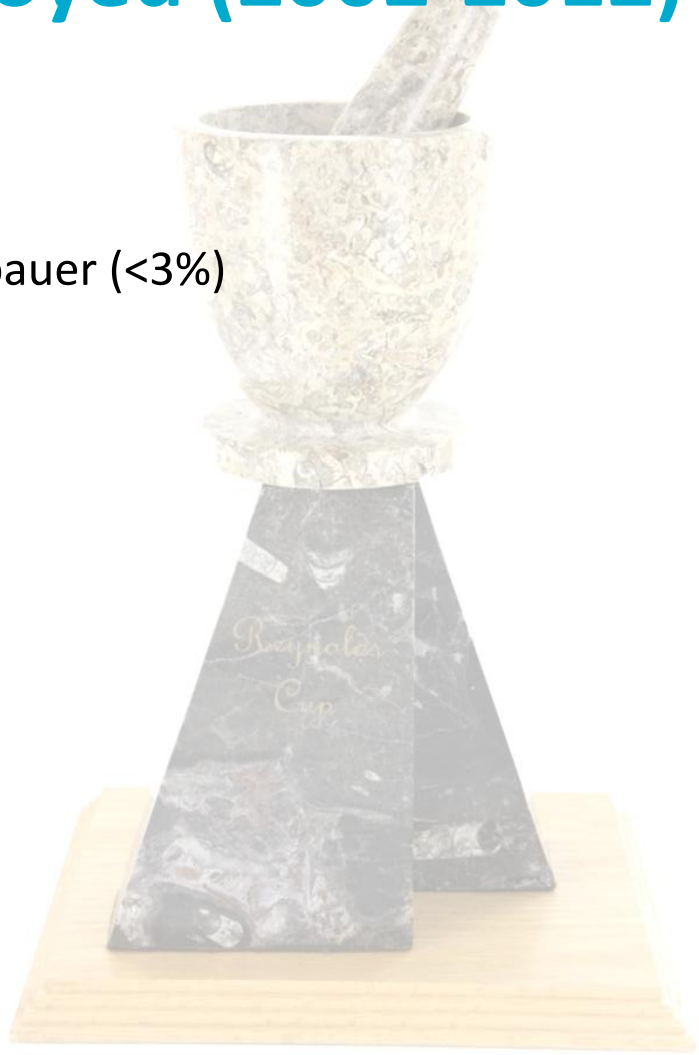
- **2002**
  1. ***Reinhard Kleeberg (Germany)***
  2. Reiner Dohrmann (Germany)
  3. Dennis Eberl (USA)
     Steve Hillier (Scotland)
- **2004**
  1. ***Oladipo Omotoso (Canada)***
  2. Douglas McCarty (USA)
  3. Steve Hillier (Scotland)
     Michael Plötze (Switzerland)
- **2006**
  1. ***Douglas McCarty (USA)***
  2. Steve Hillier (Scotland)
  3. Reinhard Kleeberg (Germany)
- **2008**
  1. ***Steve Hillier (Scotland)***
  2. Oladipo Omotoso (Canada)
     Reinhard Kleeberg and Kristian Ufer (Germany)
  3. Katja Emmerich & Annett Steudel (Germany)
     Steve Chipera (USA)
     Dennis Eberl & Alex Blum (USA)
     Mark Raven (Australia)
- **2010**
  1. ***Mark Raven and Peter Self (Australia)***
  2. Denny Eberl, Alex Blum, Mario Guzman, Marc Serravezza and Keith Morrison (USA)
  3. Reinhard Kleeberg and Kristian Ufer (Germany)
- **2012**
  1. ***Michael Plötze (Switzerland)***
  2. Steve Hillier (Scotland)
  3. Reinhard Kleeberg and Robert Möckel (Germany)

Participants of the 2012 Reynolds Cup

- 74 registrants
- 25 countries
  - Australia (4)
  - Belgium (1)
  - Canada (1)
  - China (1)
  - Colombia (2)
  - Denmark (1)
  - France (6)
  - Germany (11)
  - Greece (2)
  - Hungary (1)
  - India (1)
  - Italy (1)
  - Kenya (1)
  - Korea (1)
  - Norway (1)
  - Poland (2)
  - Russia (6)
  - Saudi Arabia (2)
  - Slovakia (1)
  - South Africa (1)
  - Spain (2)
  - Switzerland (1)
  - Turkey (3)
  - United Kingdom (6)
  - United States of America (15)

Analytical techniques employed (2002-2012)

- Primary quantification technique
  - XRD (>97%)
  - IR, FT-IR, Raman spectroscopy, SEM/TEM, Mossbauer (<3%)
- Ancillary techniques
  - Chemical analysis (XRF, ICP, neutron activation)
  - FT-IR, VNIR reflectance
  - DTA-TGA-DSC
  - Electron microscopy (SEM/TEM-EDX)
  - Wet chemistry
  - CEC
  - Carbonate analysis
  - Surface area
  - Optical microscopy, petrography
  - Mossbauer
  - Ion chromatography

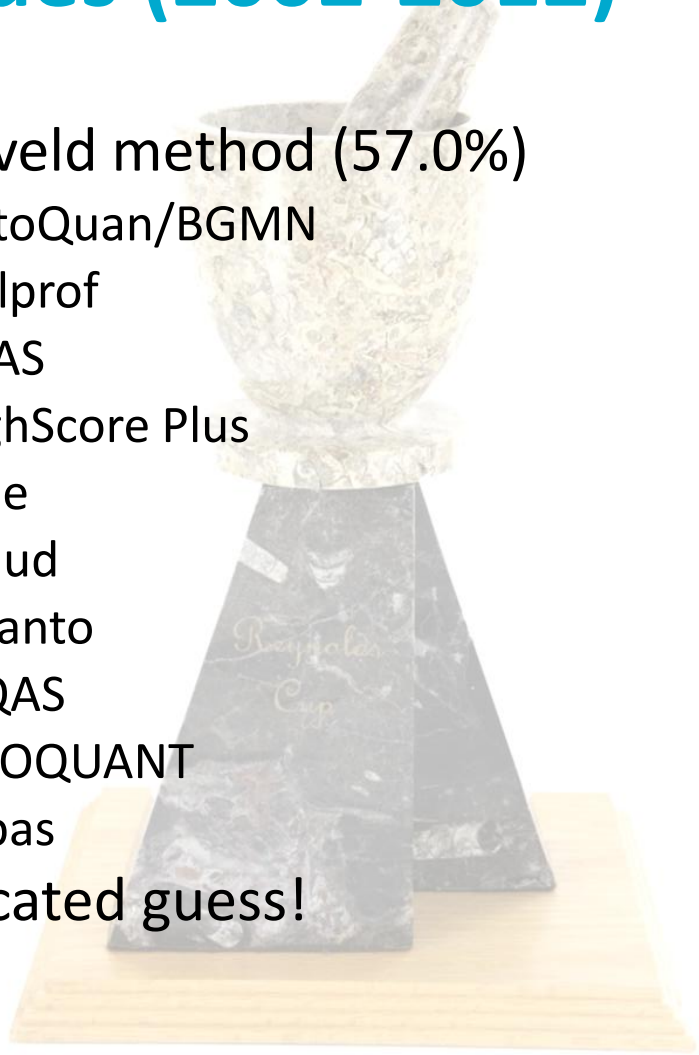


XRD techniques (2002-2012)

- Bulk pressed powders
- Magnetic fraction
- Optical separation
- Grain size separation
  - Sieving
  - Dispersion and sedimentation
- Oriented samples
  - Cation saturations
  - Heating
  - Ethylene glycol/glycerol solvation

XRD quantification techniques (2002-2012)

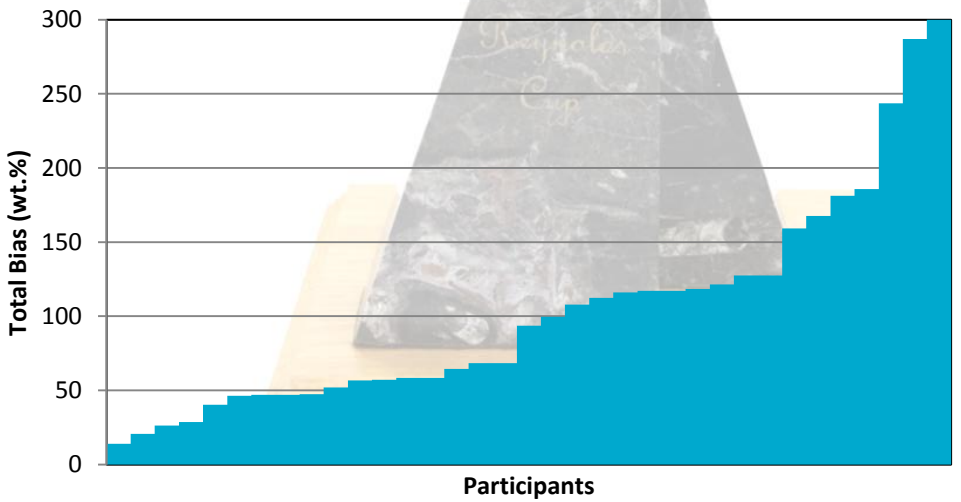
- Single peak methods (21.0%)
  - Matrix flushing
  - NEWMOD
  - RIR ICDD-PDF
- Whole pattern techniques (19.5%)
  - Arquant
  - Fullpat
  - Hillier
  - Quanta
  - Rancourt and Dang
  - RockJock
  - X-LS Mineral
- Rietveld method (57.0%)
  - AutoQuan/BGMN
  - Fullprof
  - GSAS
  - HighScore Plus
  - Jade
  - Maud
  - Quanto
  - RIQAS
  - SIROQUANT
  - Topas
- Educated guess!



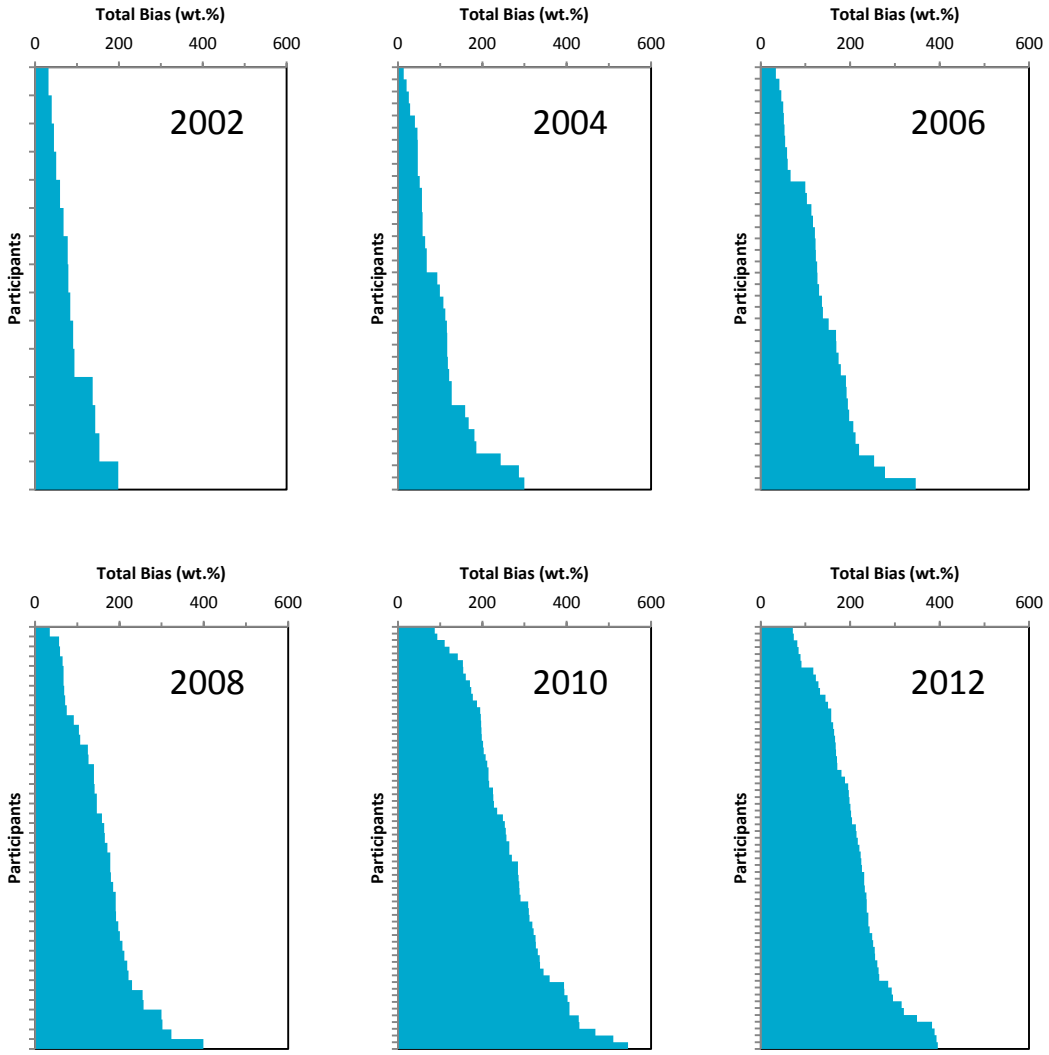
Results (2004)

Mineral	RC2-1(wt.%)			RC2-2(wt.%)			RC2-3(wt.%)		
	(wt.%)	Adj. (wt.%)	Δ	(wt.%)	Adj. (wt.%)	Δ	(wt.%)	Adj. (wt.%)	Δ
Quartz	24.8	25.1	0.3	45.7	47.0	1.3	14.7	14.8	0.1
K-Feldspar	8.5	8.3	0.2	9.2	9.5	0.3	2.1	2.9	0.8
Albite	6.5	8.3		4.0	11.7		0.0	3.7	
Oligoclase	0.0			6.7			2.9		
other plagioclase	0.0			0.0			0.0		
Plagioclase	6.5	8.3	1.8	10.7	11.7	1.0	2.9	3.7	0.8
Calcite	5.0	5.3	0.3	0.0		0.0	18.6	17.7	0.9
Dolomite	2.0			0.0			6.0		
Ankerite	0.0			0.0			0.0		
Dolomite	2.0	2.1	0.1	0.0	0.0	0.0	6.0	5.8	0.2
Magnesite	0.0		0.0	0.0		0.0	4.9	4.6	0.3
Halite	0.0		0.0	0.0		0.0	1.5	1.7	0.2
Anhydrite	0.0		0.0	0.0		0.0	14.6	14.6	0.0
Pyrite	2.5	2.4	0.1	0.0		0.0	0.0		0.0
Hematite	0.0		0.0	2.5	2.4	0.1	0.0		0.0
Anatase	0.1		0.1	1.5	1.4	0.1	0.0		0.0
Rutile	0.0		0.0	1.5	1.2	0.3	0.0		0.0
Total Non-clay	49.4	51.5	2.9	71.1	73.2	3.1	65.3	65.8	3.3
Kaolinite	16.0	15.2		9.9	14.4		0.0	0.1	
Dickite	0.0			5.5			0.0		
Kaolinite group	16.0	15.2	0.8	15.4	14.4	1.0	0.0	0.0	0.0
Illite 1Mt	10.5			5.5			0.0		
I/S mixed layer	10.1	25.0		0.0	10.2		0.0		
Montmorillonite	9.5	5.0		0.0			8.0	6.3	
Muscovite 2M1	0.0			5.0			17.1	18.4	
other dioct. 2:1 phase	0.0			0.0			0.0		
Total dioct 2:1 clay and mica	30.1	30.0	0.1	10.5	10.2	0.3	25.1	24.7	0.4
Chlorite	4.5	3.3	1.2	3.0	2.3	0.7	9.6	9.4	0.2
Total clay	50.6	48.5	2.1	28.9	26.9	2.0	34.7	34.1	0.6
Total identified	100.0	100.0	5.0	100.0	100.1	5.1	100.0	99.9	3.9
Bias non-clay		2.9			3.1			3.3	
Bias clay		2.1			2.0			0.6	
Total bias		5.0			5.1			3.9	
Sum + Misidentified					14.0				

Nr	Participant	Total bias RC2/1	Total bias RC2/2	Total bias RC2/3	Sum bias
1	19	5.00	5.10	3.90	14.00
2	13	7.20	4.80	8.60	20.60
3	1	13.60	8.20	4.50	26.30
4	15	3.60	12.20	12.90	28.70
5	3	15.00	6.30	19.00	40.30
6	17	13.70	15.00	17.70	46.40
7	57	17.00	16.60	13.40	47.00
8	47	15.00	15.00	17.10	47.10
9	42	15.80	10.80	20.80	47.40
10	29	22.20	16.00	13.80	52.00

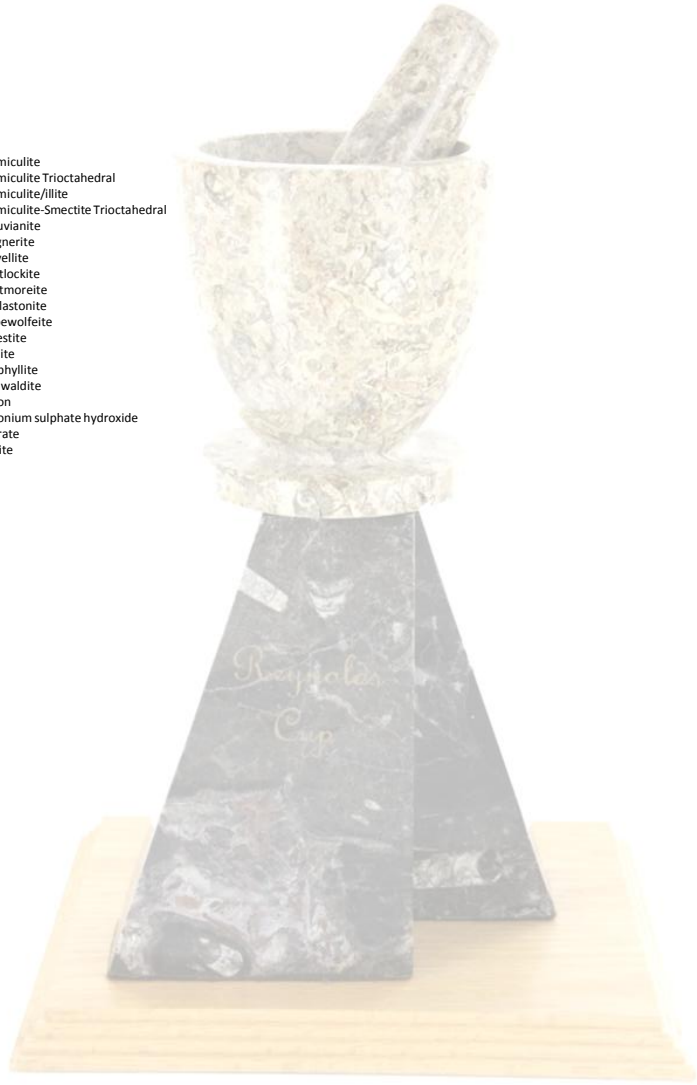


Total biases for all contests (2002-2012)



Misidentified phases

- Actinolite
- Aegerine
- Aerinite
- Akaganeite
- Albite/anorthite
- Allophane
- Alluaudite
- Almandine
- Al-Mg
- AlO
- Alumina gamma
- Aluminite
- Alunite
- Alunogen
- Amorphous
- Amorphous (Allophane)
- Amorphous KAlSi3O8
- Amorphous Si
- Amorphous SiO2
- Amorphous Volcanic Glass
- Amphibole
- Analcime
- Anatase
- Andesine
- Anhydrite
- Ankerite
- Anorthite
- Antigorite
- Antlerite
- Apatite
- Aragonite
- Arcanite
- Arsenolite As2O3
- Augite
- Barite
- Bazalt
- Berthierine
- Biotite
- Birnessite
- Bromcarnallite
- Brookite
- Brucite
- Brushite
- Bytownite
- C6H5O3PZn
- Calcite
- CaMg2Al16O27
- Carbonate-fluorapatite
- Carnallite
- CaSiO3
- Celestine
- Chabazite
- Chalcosite
- Chlorargyrite
- Chlorite Dioctahedral
- Chlorite Trioctahedral
- Chlorite-Montmorillonite(Tri)
- Chlorite-Smectite Trioctahedral
- Chlorite-vermiculite
- Chromite
- Chrysotile
- Clinochlore
- Clinoenstate
- Clinoptilolite
- ClinoPyroxene
- Clinozoisite
- Cordierite
- Corrensite
- Corundum
- Cotunnite
- Cristobalite
- Cryptohalite
- Crysotile
- Diaspore
- Dickite
- Dickite/Nacrite
- Diopside
- Dolomite
- Dolomite/Ankerite
- Elpidite
- Enstatite
- Epidote
- Euclase
- Faujasite
- Fe oxide
- Fedorite
- Feldspar (Kspar)
- Ferrihydrite
- Ferrite magnesian
- Fluorapatite
- Forsterite
- Galeite
- Garnet
- Gehlenite
- Gibbsite
- Gismondine
- Glass/Obsidian
- Glauberite
- Glauconite
- Goethite
- Gypsum
- Halite
- Halite potassian
- Halloysite
- Hectonite
- Hedenbergite
- Hematite
- Hercynite
- Heulandite
- Hexahydrite
- Hornblende
- Hotsonite
- Hyalophane
- hydrated Ca-Mg carbonate
- Hydrocalumite
- Hydrotalcite
- Hydroxyapophyllite
- Hydroxylapatite
- Hypersthene
- Illite Tri
- Ilmenite
- ilterstratified (tri)
- Iron
- Iron Silicon
- Jarosite
- KAlSiO4
- Kaolinite
- kaolinite/smectite
- Kaolinite-Chlorite
- K-feldspar
- Kieserite
- K-rich Chlorite
- Kutnohorite
- Laueite
- Laumonite
- Lepidocrocite
- Leucite
- Lime
- Lithosite
- Lizardite
- Magnesioferrite
- Magnesite
- Magnetite
- Malachite
- Manganite
- Melantenite
- Mg7Zn3
- Mg-calcite
- MgSO4
- Mica
- Mica Trioctahedral
- Mica-Vermiculite Trioctahedral
- Microcline
- Missing
- Monazite
- Monohydrocalcite
- Montmorillonite (Tri)
- Moschellandsbergite
- Mullite
- Nacrite
- Na-Feldspar
- Natrolite
- Nepheline
- Nitride Silicon
- Nordstrandite
- Norrishite
- Oligoclase
- Olivine
- Opal
- Opal CT
- Orthoclase
- OrthoPyroxene
- Osumilite
- Others not precisely identified
- oxide 1
- oxide 2
- Palygorskite
- Periclase
- Perovskite
- Phillipsite
- Phlogopite (2M1)
- Phlogopite (mica-trioctahedral)
- phosphate hydrate
- Plagioclase
- Portlandite
- Potarite
- Prehnite
- Pseudobrookite
- Pumpellyite
- Pyrite
- Pyrolusite
- pyrophyllite 1T
- pyrophyllite 2M
- Pyroxene
- Pyroxene (Augite)
- Pyroxene (Ferroan Diopside)
- Pyrrhotite
- Rectorite
- Reyerite
- Rhodochrosite
- Rhodonite
- Rodolicoite
- Rutile
- Sanidine
- Saponite
- Sauconite
- Schorl
- Sepiolite
- Serpentine
- Siderite
- Siderite (Mn-rich)
- Siderite(not Mg)
- Silicon
- Silicon dioxide
- Sillimanite
- Smectite trioctahedral
- Smithsonite
- Sodalite
- Spencerite
- Sphalerite iron
- Spinel
- Staurolite
- Strontianite
- Sylvite
- Syngenite
- Szomolnokite
- Talc
- Thenardite
- Thermonatrite
- Titanite
- Titanomagnetite
- Tobermorite
- Tourmaline
- Trimerite
- Trydymite
- Tungstite
- Unidentified
- Unnamed hydrate
- Vaterite
- Vauxite
- Vermiculite
- Vermiculite Trioctahedral
- Vermiculite/illite
- Vermiculite-Smectite Trioctahedral
- Vesuvianite
- Wagnerite
- Wavellite
- Whitlockite
- Whitmoreite
- Wollastonite
- Wroewolfeite
- Wuestite
- Zeolite
- Zeophyllite
- Zinnwaldite
- Zircon
- Zirconium sulphate hydroxide hydrate
- Zoisite



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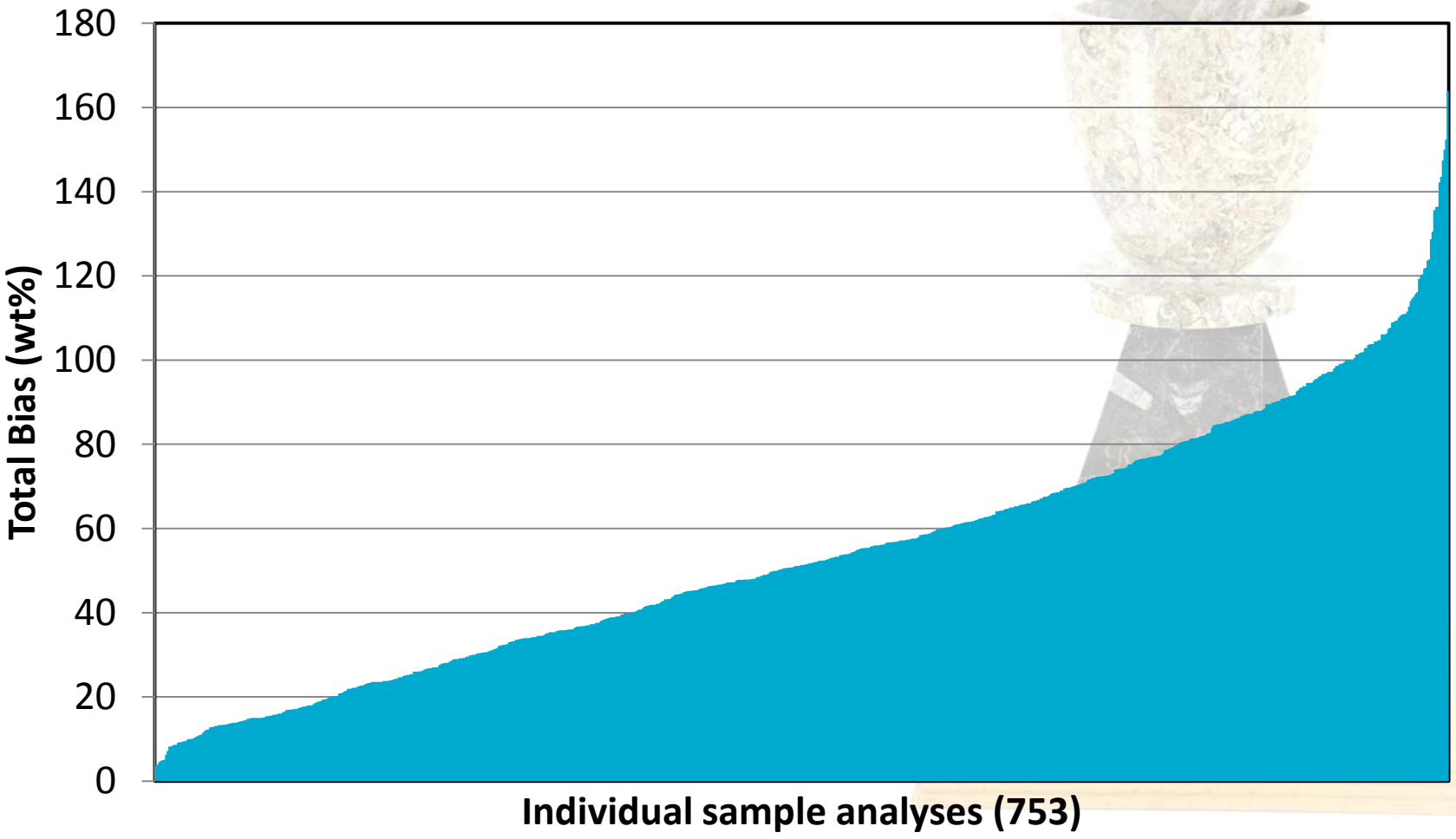
- Alluaudite
- Almandine
- Al-Mg
- AlO
- Alumina gamma
- Aluminite
- Alunite
- Alunogen
- Amorphous
- Amorphous (Allophane)
- Amorphous KAlSi3O8
- Amorphous Si
- Amorphous SiO2
- Amorphous Volcanic Glass
- Amphibole
- Analcime
- Anatase
- Andesine
- Anhydrite
- Ankerite
- Anorthite
- Antigorite
- Antlerite
- Apatite
- Aragonite
- Arcanite
- Arsenolite As2O3
- Augite
- Barite
- Bazalt
- Berthierine
- Biotite
- Birnessite
- Bromcarnallite
- Brookite
- Brucite
- Brushite
- Bytownite
- C6H5O3PZn
- Calcite
- CaMg2Al16O27
- Carbonate-fluorapatite
- Carnallite
- CaSiO3
- Celestine
- Chabazite
- Chalcosite
- Chlorargyrite
- Chlorite Dioctahedral
- Chlorite Trioctahedral
- Chlorite-Montmorillonite(Tri)
- Chlorite-Smectite Trioctahedral
- Chlorite-vermiculite
- Chromite
- Chrysotile
- Clinochlore
- Clinoenstate
- Clinoptilolite
- ClinoPyroxene
- Clinozoisite
- Cordierite
- Corrensite
- Corundum
- Cotunnite
- Cristobalite
- Cryptohalite
- Crysotile
- Diaspore
- Dickite
- Dickite/Nacrite
- Diopside
- Dolomite
- Dolomite/Ankerite
- Elpidite
- Enstatite
- Epidote
- Euclase
- Faujasite
- Fe oxide
- Fedorite
- Feldspar (Kspar)
- Ferrihydrite
- Ferrite magnesian
- Fluorapatite
- Forsterite
- Galeite
- Garnet
- Gehlenite
- Gibbsite
- Gismondine
- Glass/Obsidian
- Glauberite
- Glauconite
- Goethite
- Gypsum
- Halite
- Halite potassian
- Halloysite
- Hectonite
- Hedenbergite
- Hematite
- Hercynite
- Heulandite
- Hexahydrite
- Hornblende
- Hotsonite
- Hyalophane
- hydrated Ca-Mg carbonate
- Hydrocalumite
- Hydrotalcite
- Hydroxyapophyllite
- Hydroxylapatite
- Hypersthene
- Illite Tri
- Ilmenite
- ilterstratified (tri)
- Iron
- Iron Silicon
- Jarosite
- KAlSiO4
- Kaolinite
- kaolinite/smectite
- Kaolinite-Chlorite
- K-feldspar
- Kieserite
- K-rich Chlorite
- Kutnohorite
- Laueite
- Laumonite
- Lepidocrocite
- Leucite
- Lime
- Lithosite
- Lizardite
- Magnesioferrite
- Magnesite
- Magnetite
- Malachite
- Manganite
- Melantenite
- Mg7Zn3
- Mg-calcite
- MgSO4
- Mica
- Mica Trioctahedral
- Mica-Vermiculite Trioctahedral
- Microcline
- Missing
- Monazite
- Monohydrocalcite
- Montmorillonite (Tri)
- Moschellandsbergite
- Mullite
- Nacrite
- Na-Feldspar
- Natrolite
- Nepheline
- Nitride Silicon
- Nordstrandite
- Norrishite
- Oligoclase
- Olivine
- Opal
- Opal CT
- Orthoclase
- OrthoPyroxene
- Osumilite
- Others not precisely identified
- oxide 1
- oxide 2
- Palygorskite
- Periclase
- Perovskite
- Phillipsite
- Phlogopite (2M1)
- Phlogopite (mica-trioctahedral)
- phosphate hydrate
- Plagioclase
- Portlandite
- Potarite
- Prehnite
- Pseudobrookite
- Pumpellyite
- Pyrite
- Pyrolusite
- pyrophyllite 1T
- pyrophyllite 2M
- Pyroxene
- Pyroxene (Augite)
- Pyroxene (Ferroan Diopside)
- Pyrrhotite
- Rectorite
- Reyerite
- Rhodochrosite
- Rhodonite
- Rodolicoite
- Rutile
- Sanidine
- Saponite
- Sauconite
- Schorl
- Sepiolite
- Serpentine
- Siderite
- Siderite (Mn-rich)
- Siderite(not Mg)
- Silicon
- Silicon dioxide
- Sillimanite
- Smectite trioctahedral
- Smithsonite
- Sodalite
- Spencerite
- Sphalerite iron
- Spinel
- Staurolite
- Strontianite
- Sylvite
- Syngenite
- Szomolnokite
- Talc
- Thenardite
- Thermonatrite
- Titanite
- Titanomagnetite
- Tobermorite
- Tourmaline
- Trimerite
- Trydymite
- Tungstite
- Unidentified
- Unnamed hydrate
- Vaterite
- Vauxite
- Vermiculite
- Vermiculite Trioctahedral
- Vermiculite/illite
- Vermiculite-Smectite Trioctahedral
- Vesuvianite
- Wagnerite
- Wavellite
- Whitlockite
- Whitmoreite
- Wollastonite
- Wroewolfeite
- Wuestite
- Zeolite
- Zeophyllite
- Zinnwaldite
- Zircon
- Zirconium sulphate hydroxide hydrate
- Zoisite

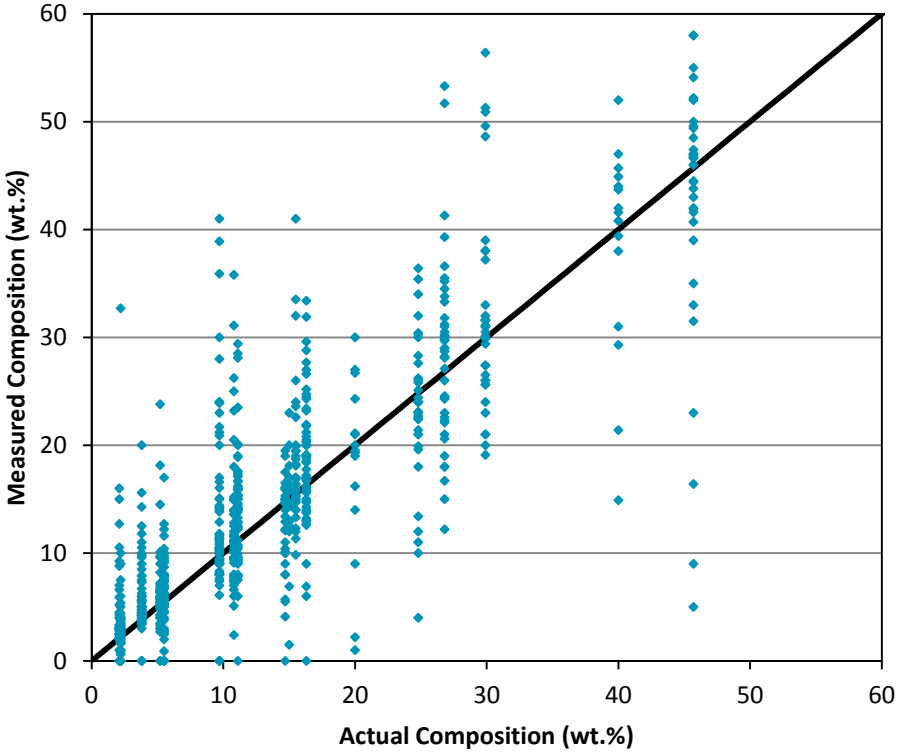
Bias for all participants and all samples (2002-2012)



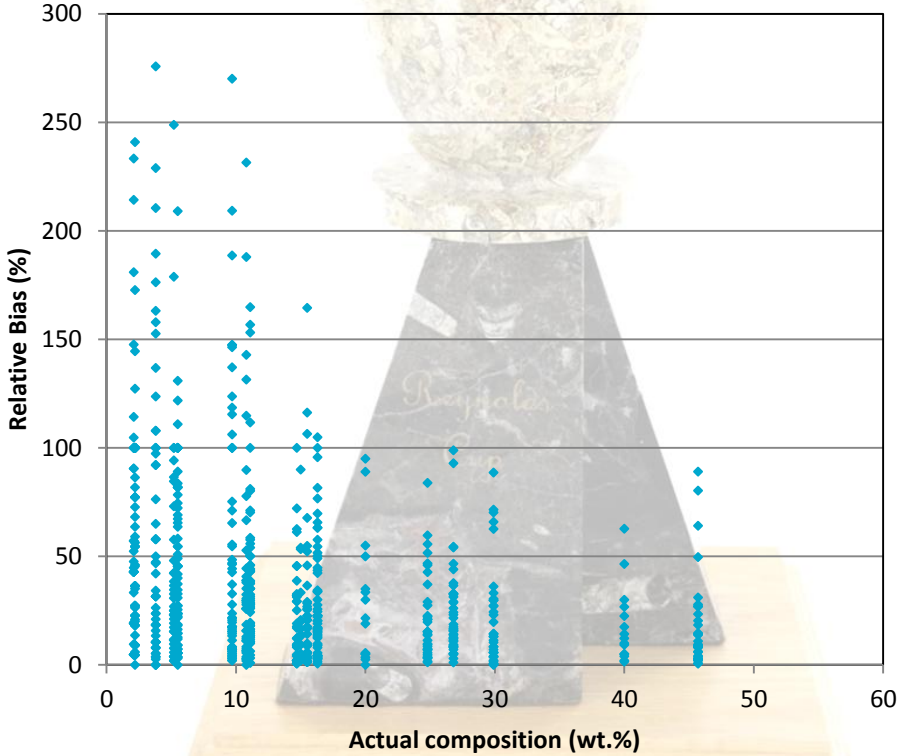
How is accuracy quantified?

Quartz

Absolute Bias (wt.%)

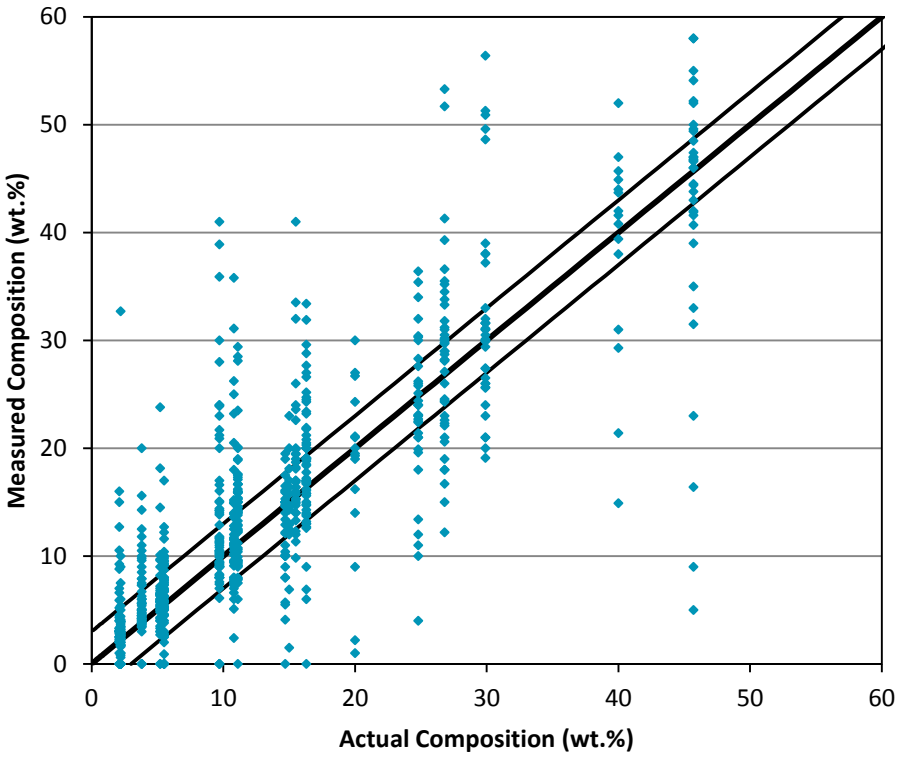


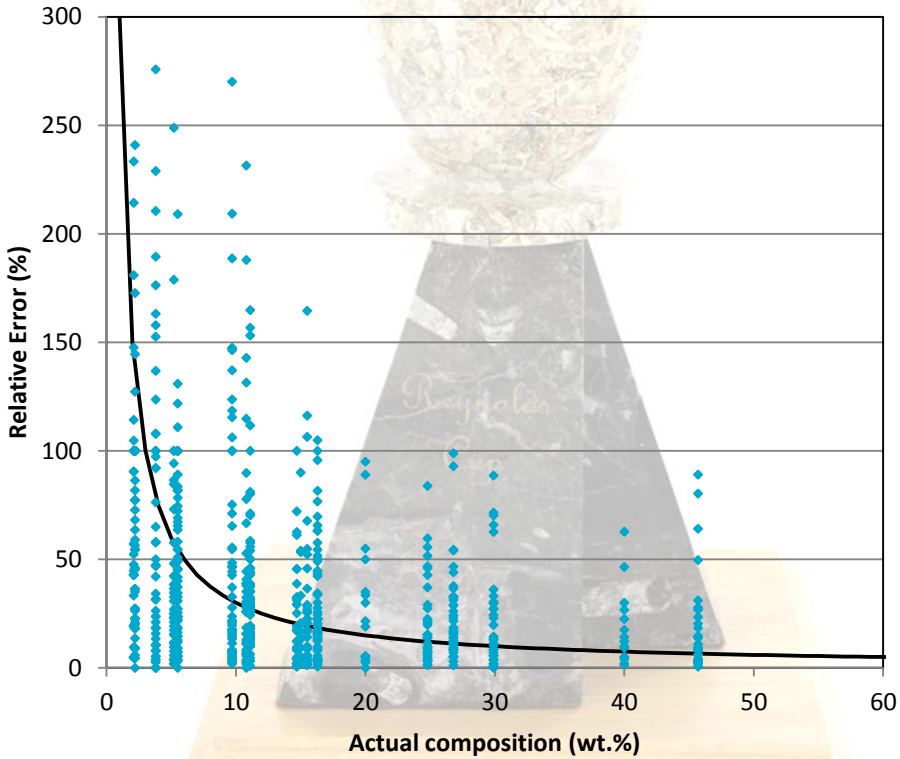
Relative Bias (%)



Quartz – ±3% absolute bias

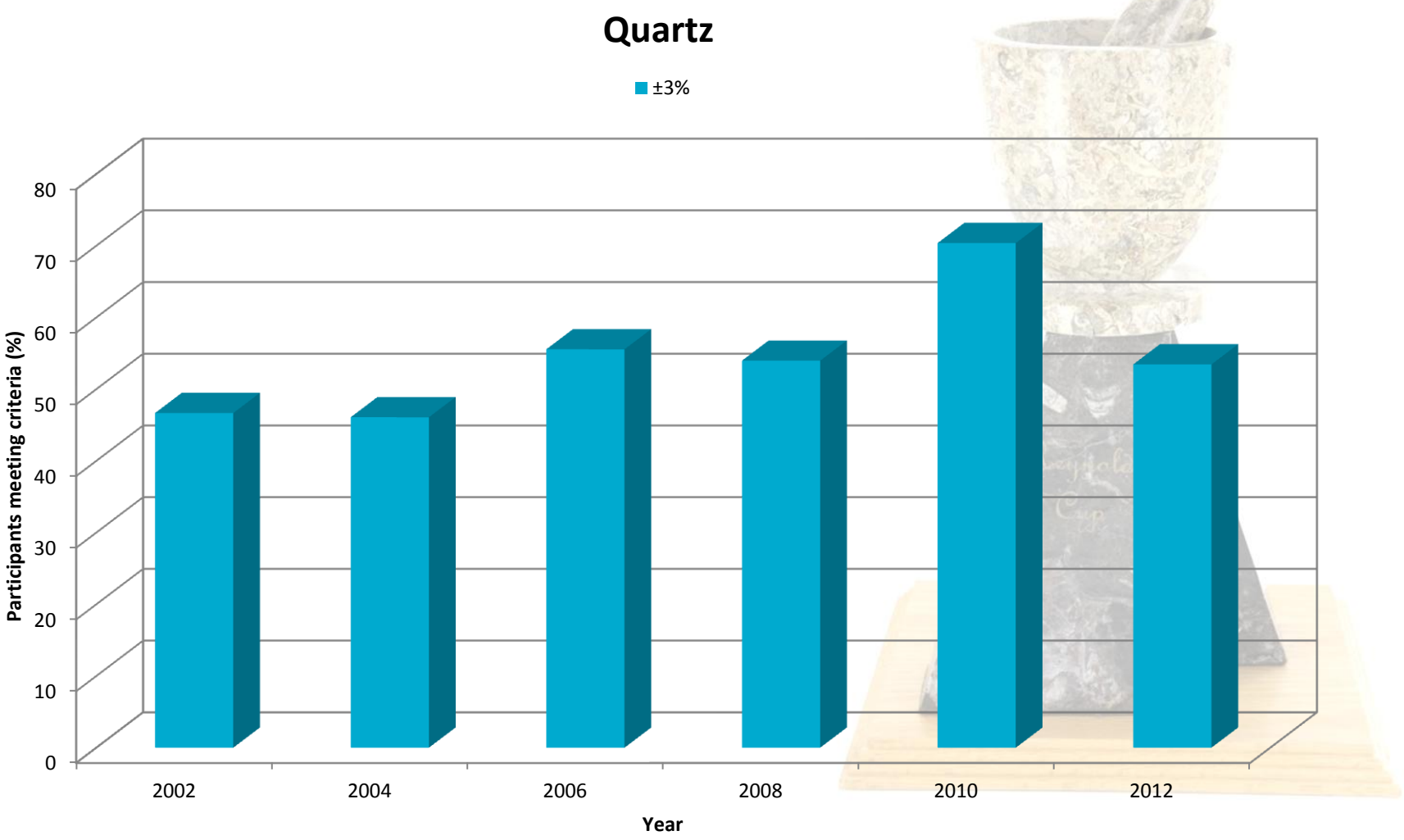
Analyses that meet the criteria: 423 (56.2%)





Calvert et al 1989. Quantitative mineral analysis of clays. *CMS Workshop Lectures Vol 1.* 154-166.

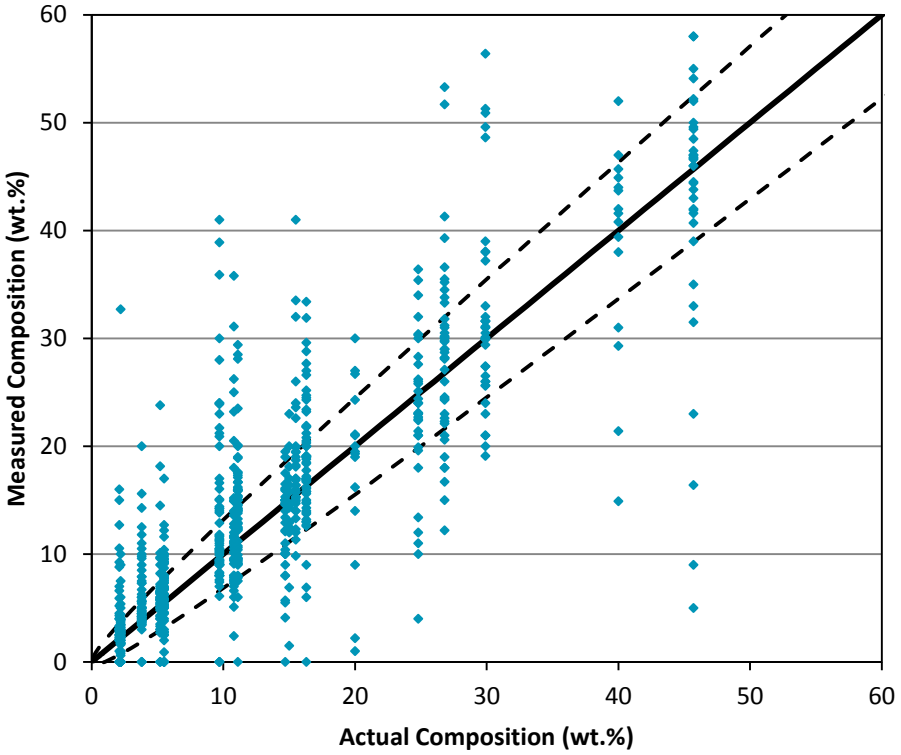
Are we there yet?



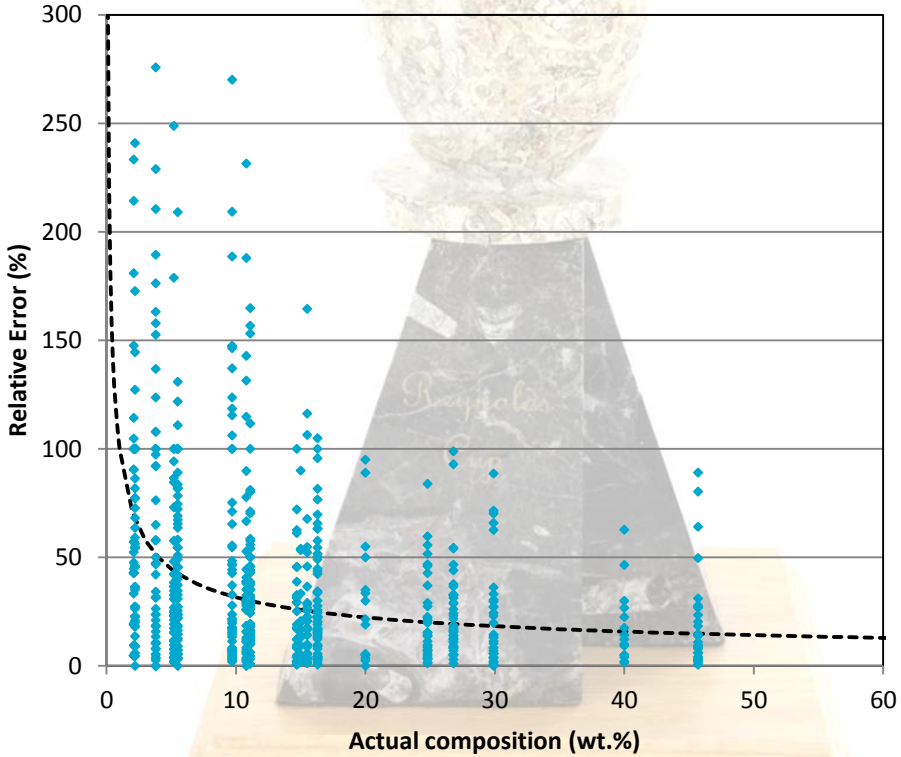
Quartz – $X^{-0.5}$

Analyses that meet the criteria: 439 (58.3%)

Absolute Bias (wt.%)

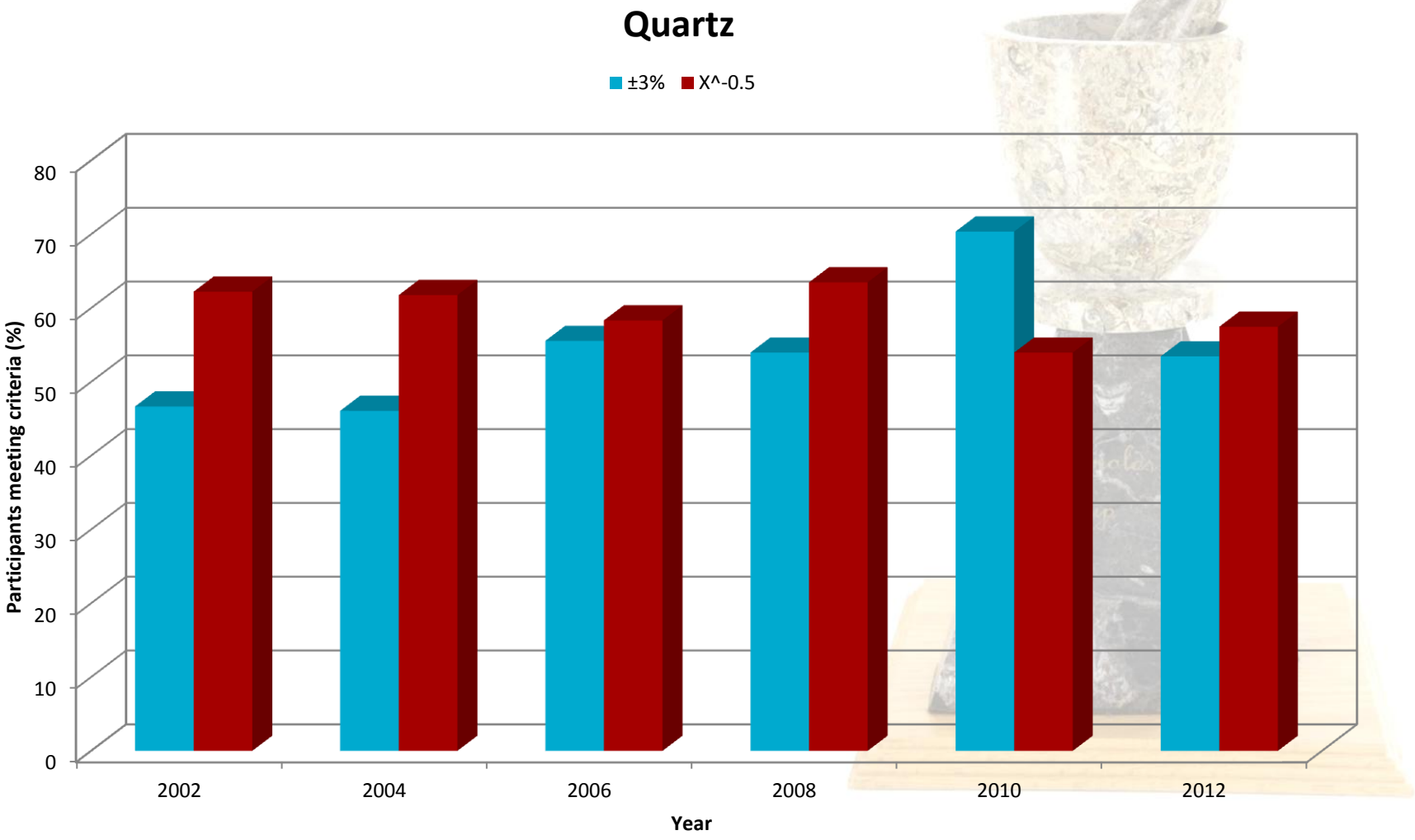


Relative Bias (%)



S. Hillier 2003. Quantitative analysis of clay and other minerals in sandstones by XRPD. *Int.Assoc.Sedimentol.Spec.Publ.* **34**, 213-251

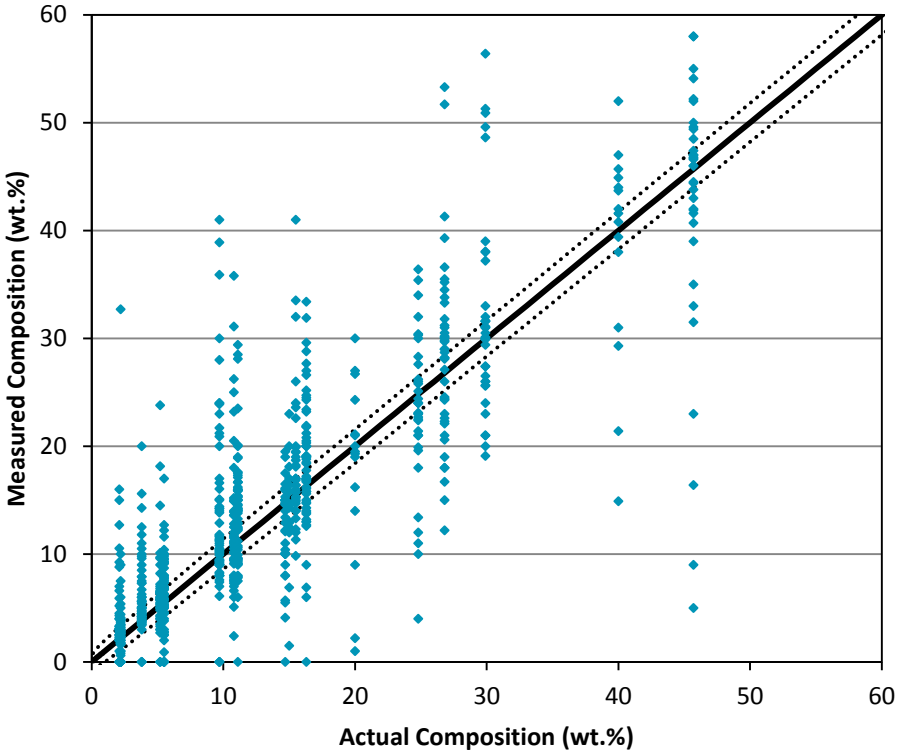
Are we there yet?



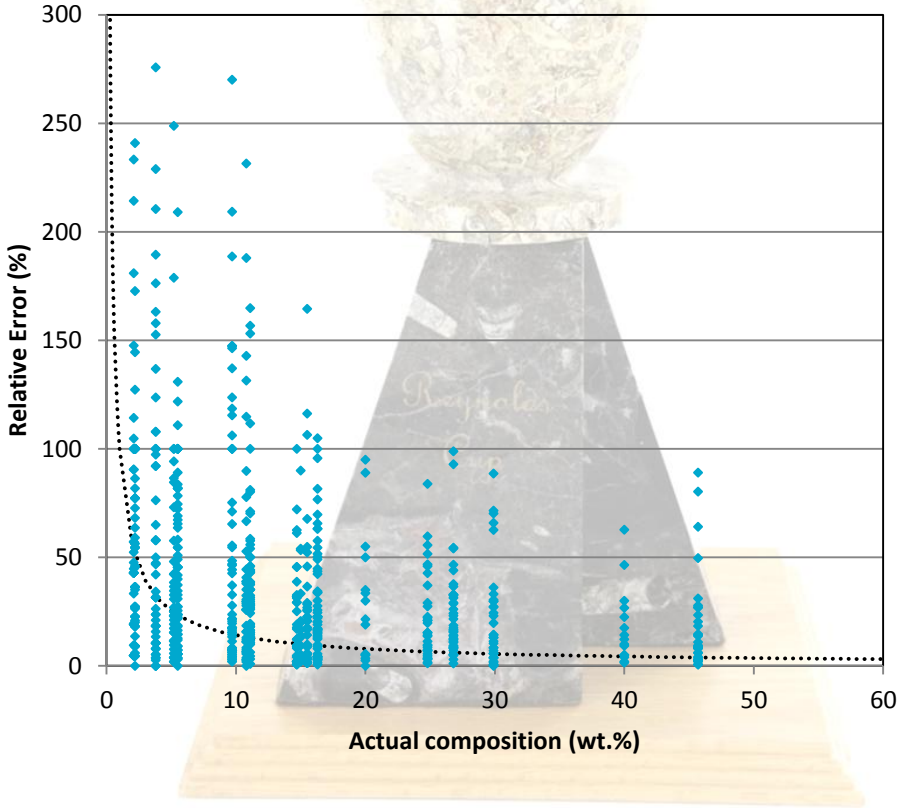
Quartz – $X^{-0.85}$

Analyses that meet the criteria: 253 (33.6%)

Absolute Bias (wt.%)

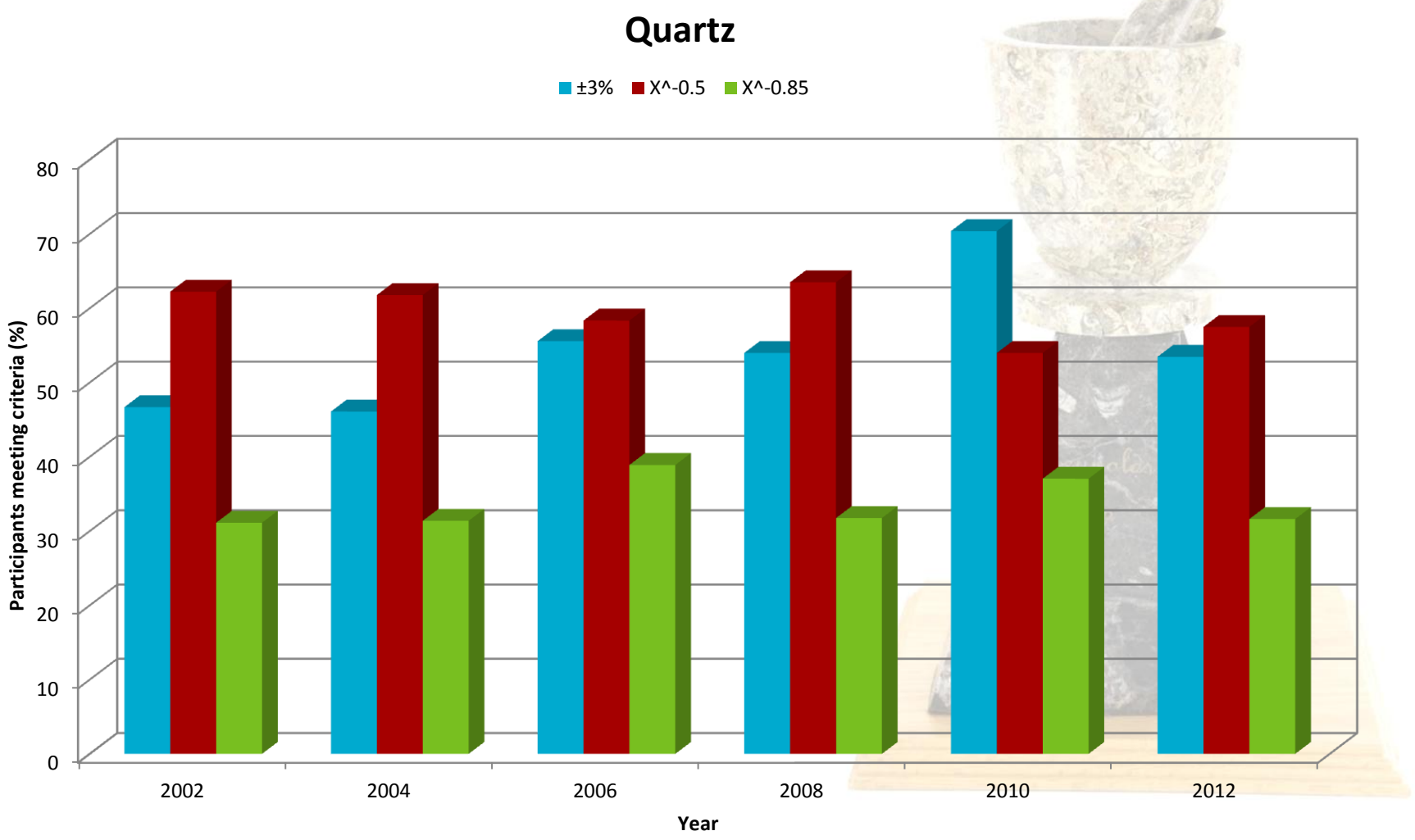


Relative Bias (%)



S. Hillier 2003. Quantitative analysis of clay and other minerals in sandstones by XRPD. *Int.Assoc.Sedimentol.Spec.Publ.* **34**, 213-251

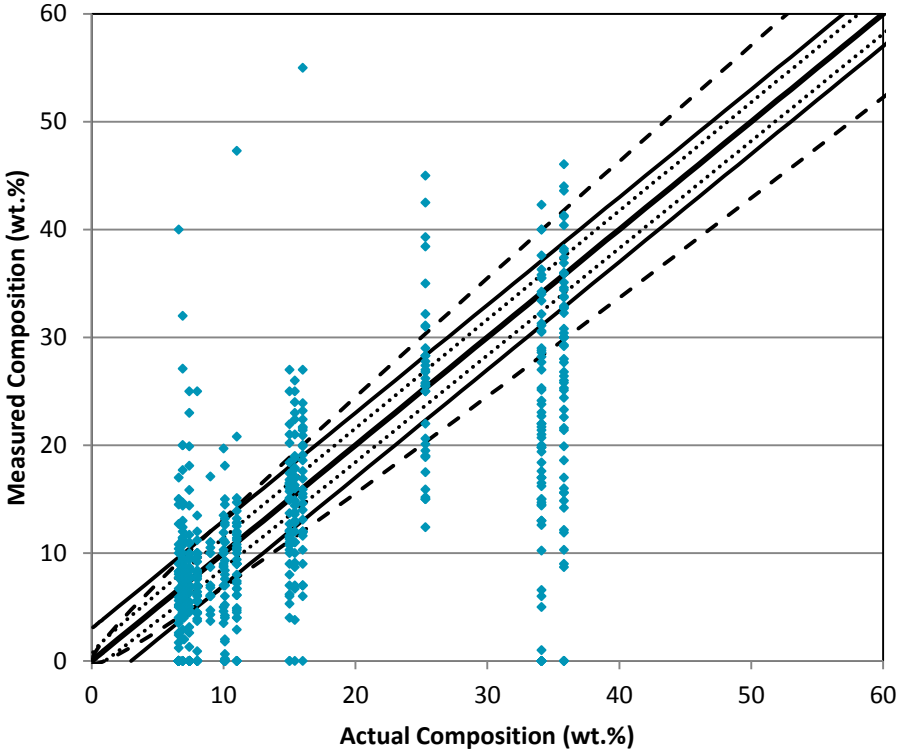
Are we there yet?



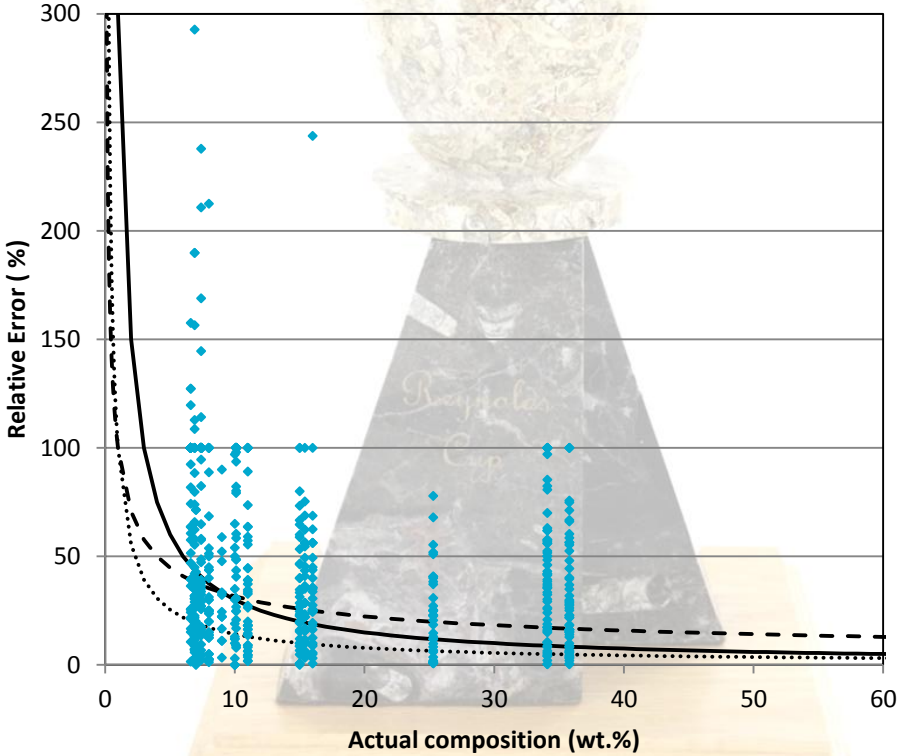
Kaolin clays – ±3%, $X^{-0.5}$, $X^{-0.85}$

Analyses that meet the criteria: 231 (37.8%), 262 (42.9%), 119 (19.5%)

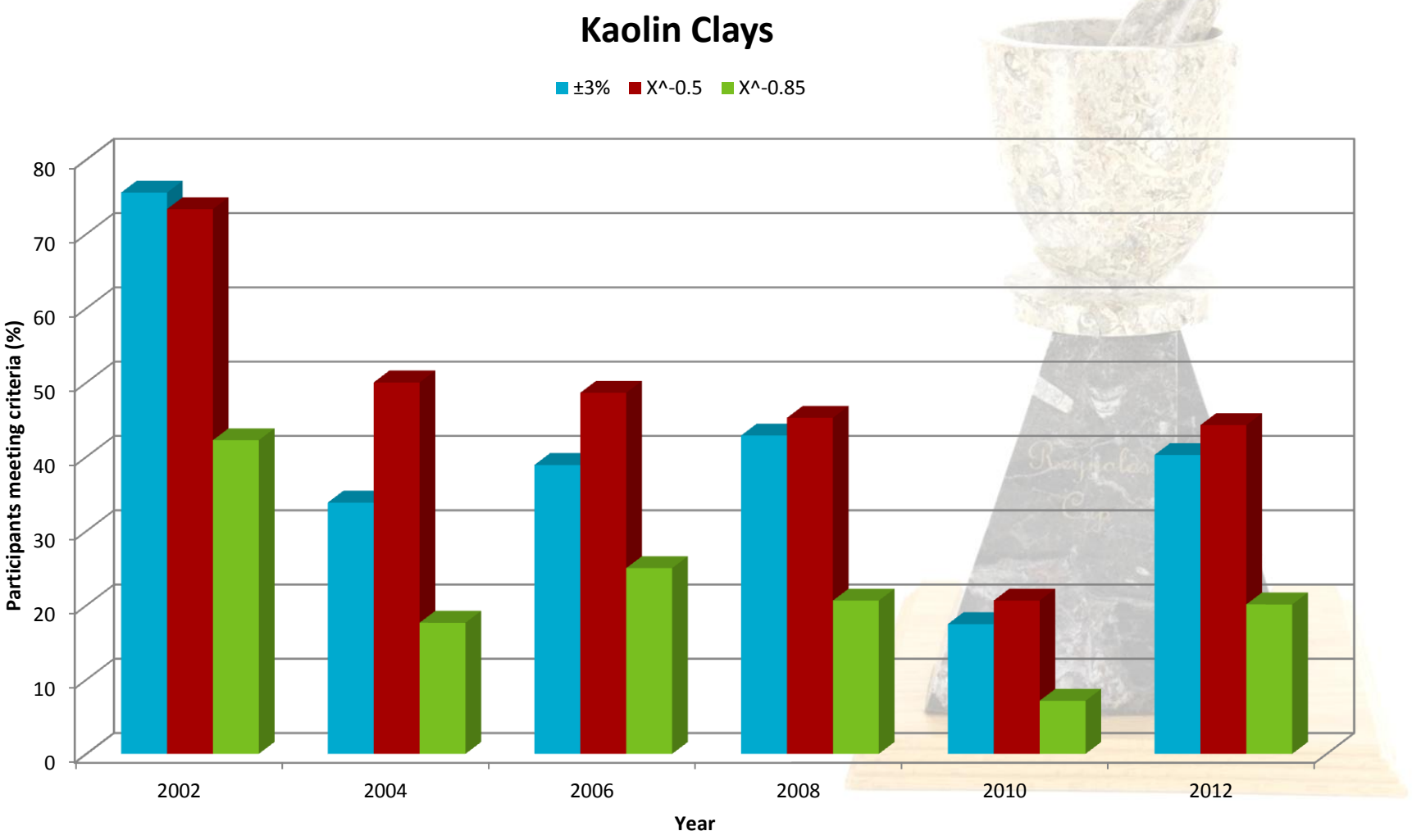
Absolute Bias (wt.%)



Relative Bias (%)



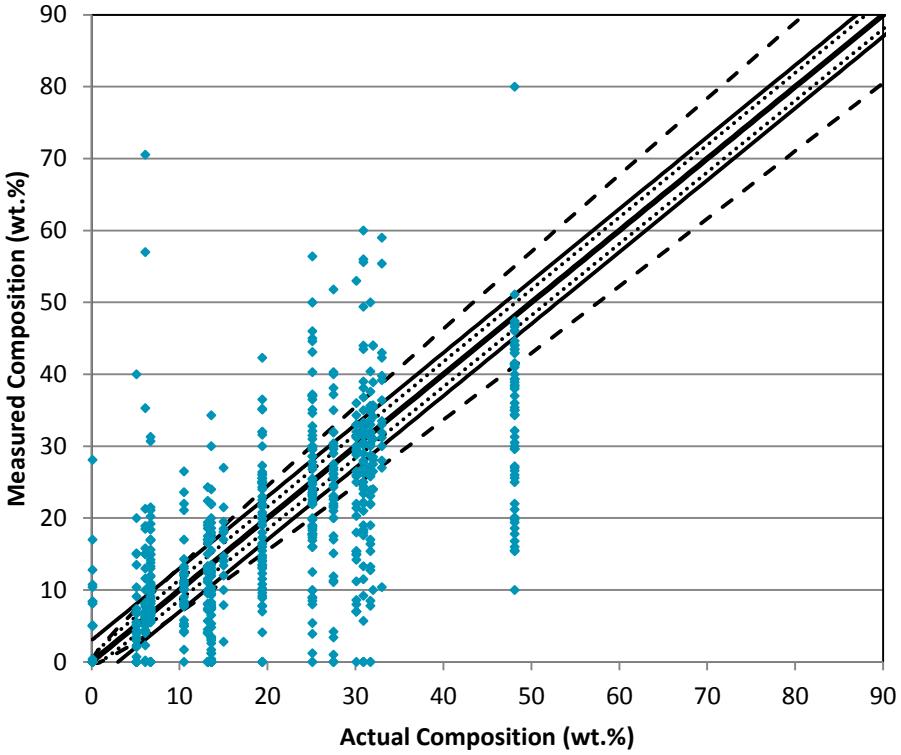
Are we there yet?



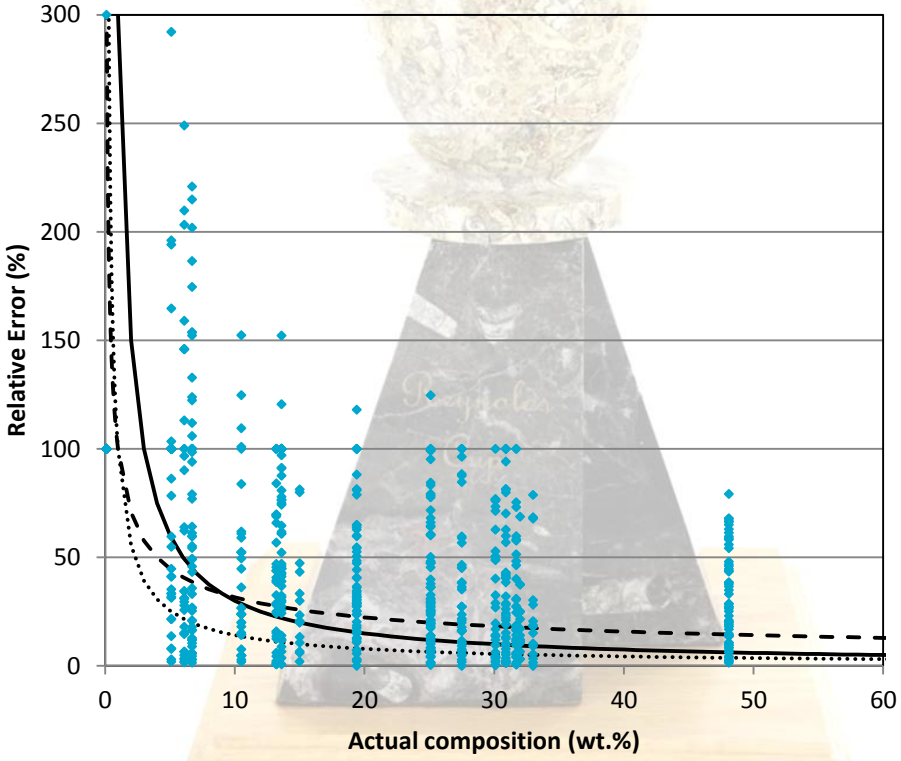
2:1 Dioctahedral clays – ±3%, $X^{-0.5}$, $X^{-0.85}$

Analyses that meet the criteria: 241 (32.4%), 300 (40.3%), 157 (21.1%)

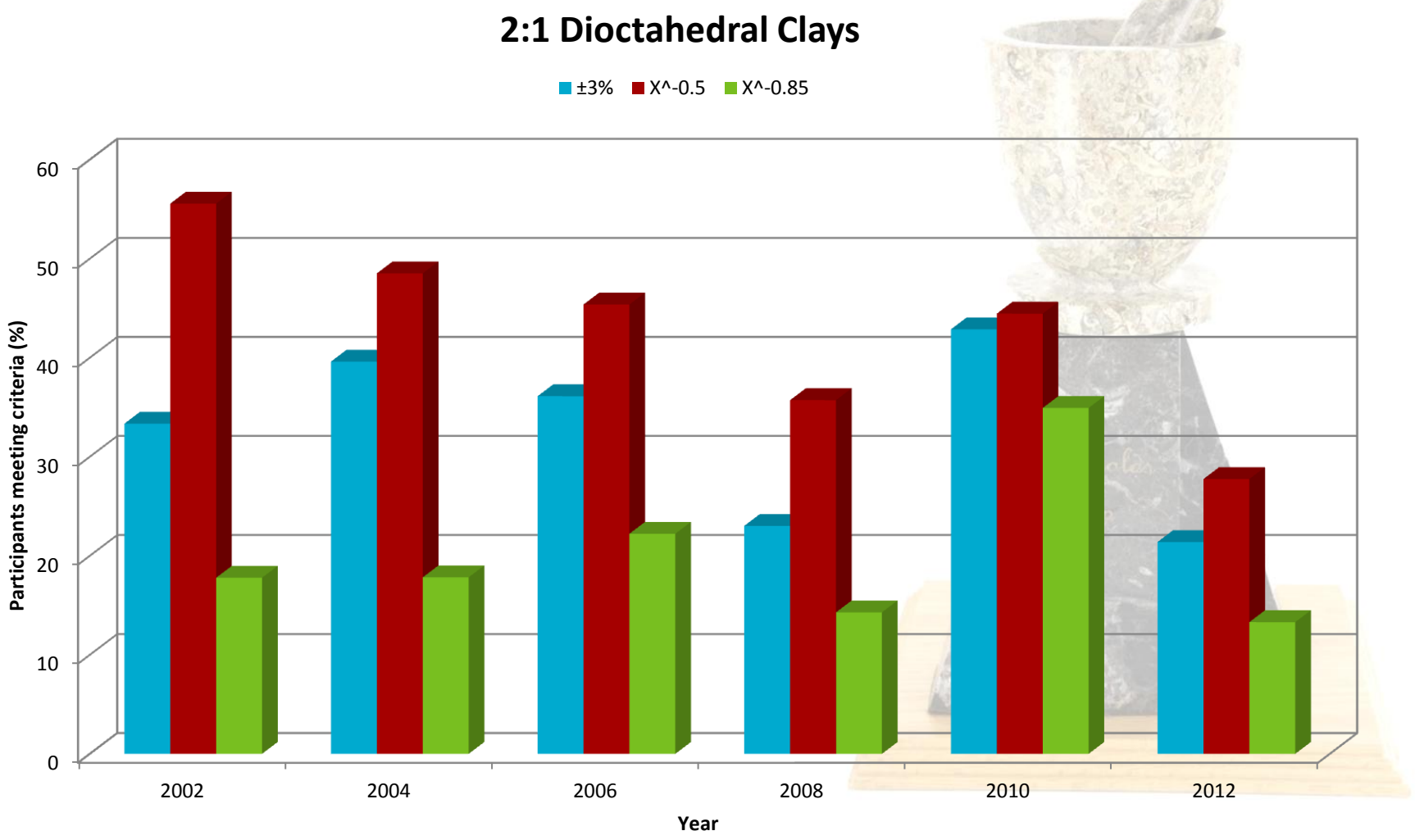
Absolute Bias (wt.%)



Relative Bias (%)



Are we there yet?

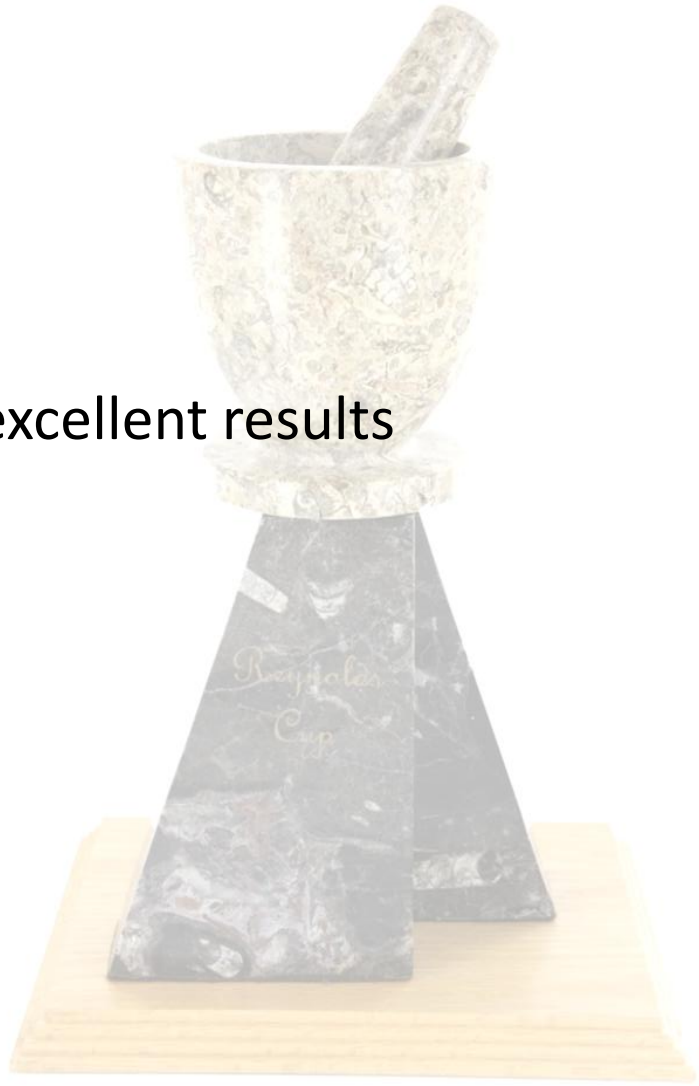


Summary

- 10 years of Reynolds Cup round robins
- 6 contests
- 18 sample mixtures
- 35 non-clays and 8 clay mineral groups
- 367 participants
- Almost 10,000 analyses
- 6 winners from 6 different countries

Conclusions

- Has accuracy improved?
  - As individuals
  - As a group
- Some participants consistently achieve excellent results
- Some participants have a long way to go
  - Sample preparation
  - Instrument settings
  - Inappropriate or incorrect use of Software

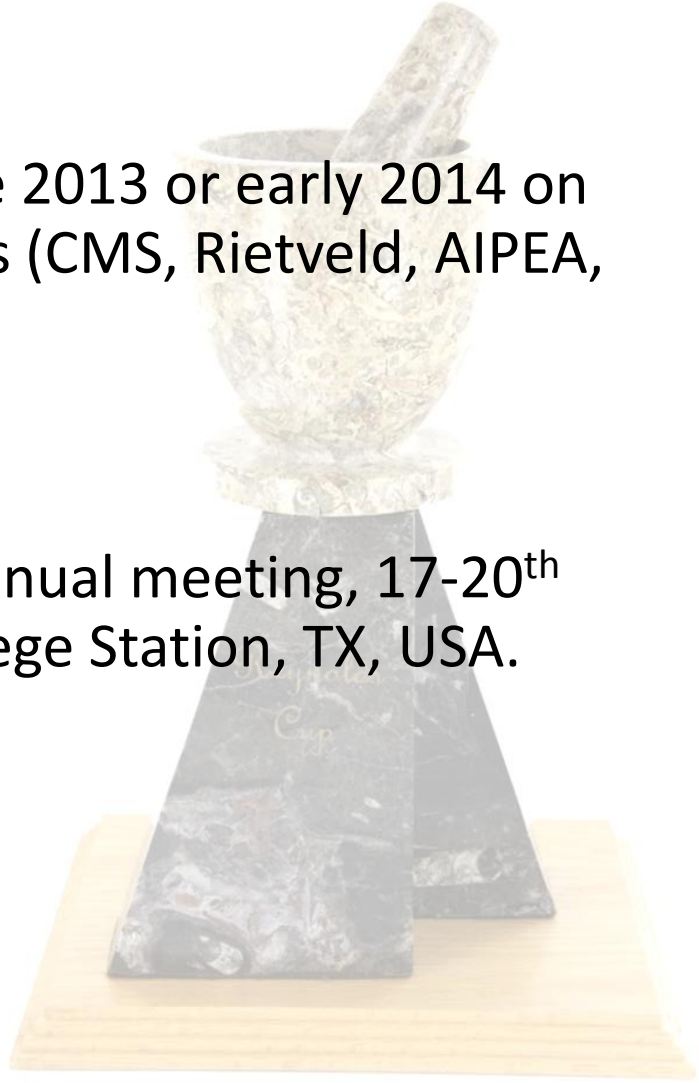


Reynolds Cup 2014

- Announcement of 7th round robin in late 2013 or early 2014 on the CMS web site, and various email lists (CMS, Rietveld, AIPEA, etc)

- Winners announced at the 2014 CMS annual meeting, 17-20th May 2014 at Texas A&M University, College Station, TX, USA.

- GOOD LUCK!



Thank you

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