Geopolymer Opportunities made from Industrial By-products in Western Australia

Ramon Skane *BEng(Hons), PhDc, Cert-EDC*

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https://reformix.com.au/

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Presentation Summary

- **Company Introduction**
- Our Team & Vision
- **Western Australia**
- **The Business Case**
- **Project Spotlights:**
  1. Large Scale Fly Ash Geopolymer: Major Learnings & QAQC
  2. Amorphous Silica Mine Tailing
  3. Other Mine Tailings & Materials
- **Conclusion**

Who are We? The (Growing) Team & Vision

Reformix is a dynamic and innovative company founded by a qualified dedicated team of industry & academic experts. Our expertise lies in the meticulous analysis, comprehensive characterisation, and innovative transformation of industrial waste materials, residues and by-products. Our focus is on converting these ~~waste materials~~ *resources* into purpose-driven, commercially viable products that redefine industry standards.

Our Team is founded on extensive experience derived from both engineering industry and academia with an emphasis on the rapidly expanding sustainability, green materials and circular economy business sectors.

Our Goal is to advance green industrial ecology, circular economy frameworks and be the leaders in green materials development and commercialisation.

What do We Do?: Eco-Concrete (Geopolymer)

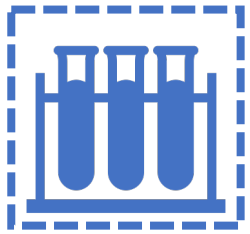
Convert Industrial By-Products into Commercialised products (e.g. geopolymer Eco-Concrete).

Industrial By-Products

Reformix™ Materials Group

Material Characterisation, IP & Product Formulation

Commercialised Products
(e.g. Geopolymers)



Other Materials & Reagents

The Problem & Reason for Change

The Global Waste Challenge:

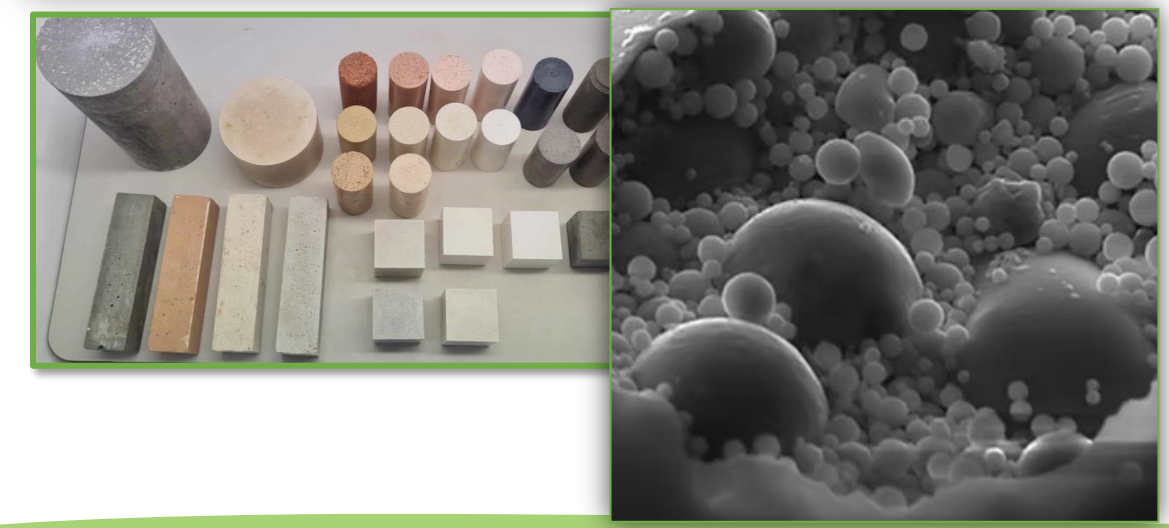
- The world generates **over 2.1 billion tonnes of solid waste/year***
- By 2050, global waste – termed *industrial by-products* – is projected to exceed 3.4 billion tonnes annually.
- Most industrial by-products are dumped in landfill, leading to:
  - Lost Material Potential
  - Economic Inefficiency
  - Significant Environmental Pollution
  - Social & Ecological Harm

Unsustainable Materials & Climate Change.

- Many industries continue to rely on natural "virgin" materials (i.e. raw materials produced mining, dredging etc.) to produce goods which are costly and deplenishing.
- Meanwhile, cheaply sourced industry by-products that could serve as commercially viable eco-friendly alternative products are underutilised.

*This only accounts for Municipal Solid Waste (MSW) source estimates. There are many other sources of waste that are untraceable, unreported and untrackable. The actual number of global by-products is *significantly* larger.

The *Reformix™* Solution



Manufacturing Opportunities with Industrial By-products:

- We see “Wastes” as raw materials, made to poor specifications: When properly formulated, these materials can meet commercial and environmental standards, offering significant value.
- Due to the high volume and disposal costs associated with industrial by-products, they can be sourced affordably.
- Cheaper raw materials enable the creation of economically and environmentally competitive products with higher profit margins compared to conventional products made from “virgin” materials.
- A Win/Win Solution: Both industry by-product suppliers and customer offtakes benefit by lowering their waste footprint, minimising greenhouse gas emissions (GHGs) and reducing total financial costs.

Our Approach:

- **Core Focus:** R&D innovation to *reform* industrial by-products into market-ready commercial products.
- **Key Value:** Reduces waste & GHGs, creates sustainable and commercially viable economically competitive materials.
- ***Geopolymer Technology***

Concrete – The Market

W.A. Concrete
777 million
$/annum (2019)

Australian Concrete
4.4 Billion
$/annum (2017)

South-East Asia Concrete
129 Billion
$/annum (2015)

Regular Ordinary Portland Cement (OPC) Concrete:

- Concrete is the most widely manufactured product in the world and responsible for ~8% GHG emissions.
- Made unsustainably from virgin materials.
- Reforming industrial by-products into valuable/ commercial products in the green/environmental concrete market is a 3.7 Billion USD industry with a projected 11.4% Compound annual growth rate (CAGR)*.

*https://www.cognitivemarketresearch.com/regional-analysis/asia-pacific-green-concrete-market-report.

PAGE

Geopolymer Opportunities in Western Australia:

- The W.A. mining industry is worth ~$200 Billion AUD.
- Australian Commodities, global% (2020) and their by-product:product ratios include:
  - 38% global Iron Ore [~ 3 tonnes tailings/ t]
  - 46% global Lithium [~ 2.5 tonnes tailings/t]
  - 48% Alumina + Bauxite Ore [~ 3 tonnes tailings /t].
  - Others include silica, gold, nickel, opal, lead, copper, zinc… etc.
- No local access to GGBFS, MK or alkaline reagents ;
  We have to innovate.

Potential Industry By-product Feedstocks

ALUMINOSILICATE PRECURSORS

- Coal Industry fly ash
- Natural & By-Product clays
- By-products from alumina processing
  - Red mud and
  - spent process liquor
- Agricultural By-products:
  - Hemp Hurds
  - Rice Husk Ash
  - Other Biomasses (etc.)
- Opaline Amorphous Silica
- Silica fume from the manufacture of silicon
- By-products from the mining industry:
  - Lithium Aluminosilicate Residue (LASR) / Mine Tailings
  - Iron Ore Tailings
  - Other Mining Tailings (Ni, Co etc.).

COARSE AND FINE AGGREGATES

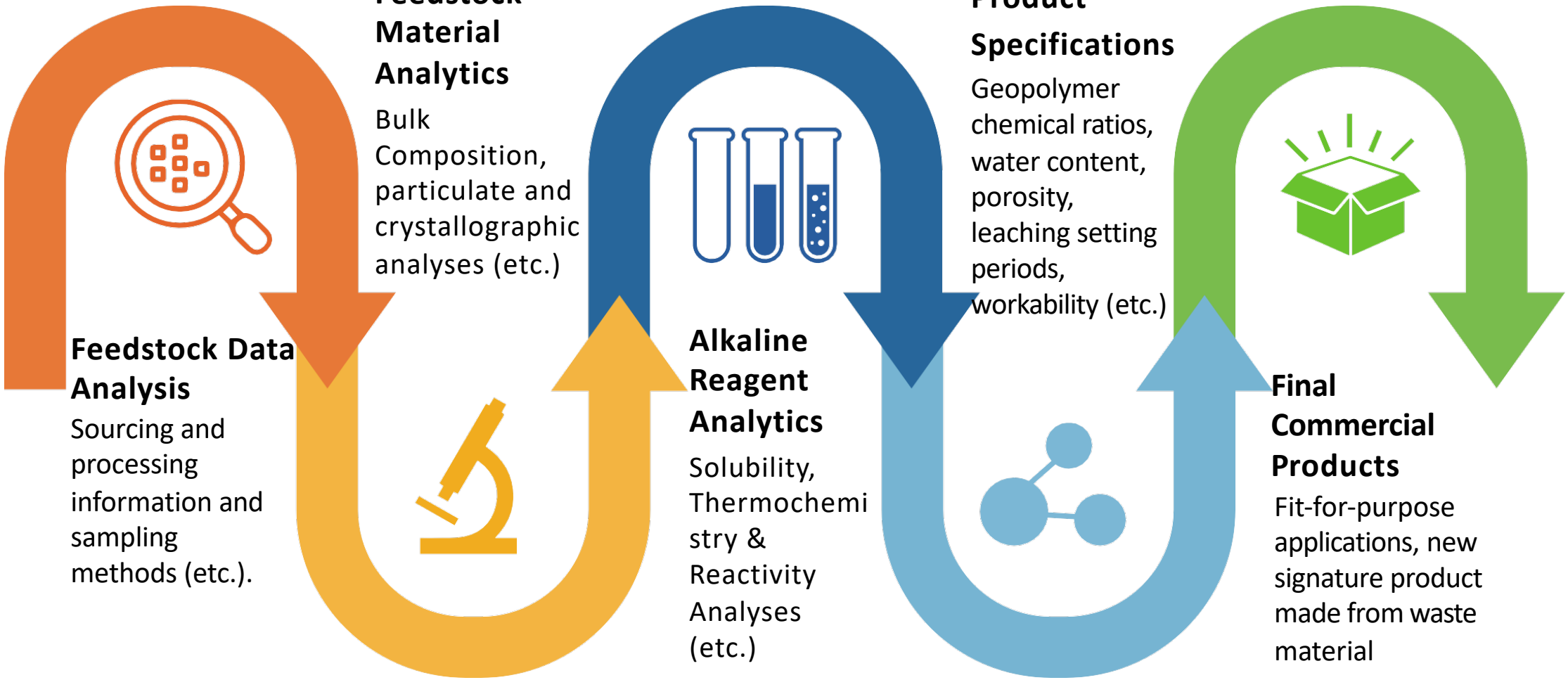
- Construction and demolition waste
- Coal bottom ash
- Fly ash cement aggregates
- By-products from alumina processing, including bauxite refining residue (red mud) and spent process liquor
- Sustainable materials such as mixed recycled aggregates or synthetic aggregates produced from waste glass, rubber, crushed recycled concrete, etc.
- By-products from mineral sands processing
- By-products from lithium processing
- Biomass from hemp and/or waste from the manufacture of medicinal cannabis

REAGENT CHEMICALS

- Commercial Industrial Chemicals
- Recycled Glass
- Recycled Water

Geopolymer Opportunities in Western Australia:

The R&D Laboratory Process



Project Spotlight 1: Successful Fly Ash Geopolymer Field Trials

Opportunity:

The global construction industry is shifting towards sustainability, driven by strict environmental standards set by governments and organisations.

- Eco-**Concrete** enhances the marketability of construction projects due to its superior qualities and reduced environmental impact.
- **Independent NATA External Testing** demonstrates that Eco-Concrete can meet high compressive strengths, up to 80 MPa.
- **Several Pilot field trials have been undertaken with large batches of Eco-Concrete being mixed, poured and tested** at local Australian concrete batching plant utilising our team's expertise.

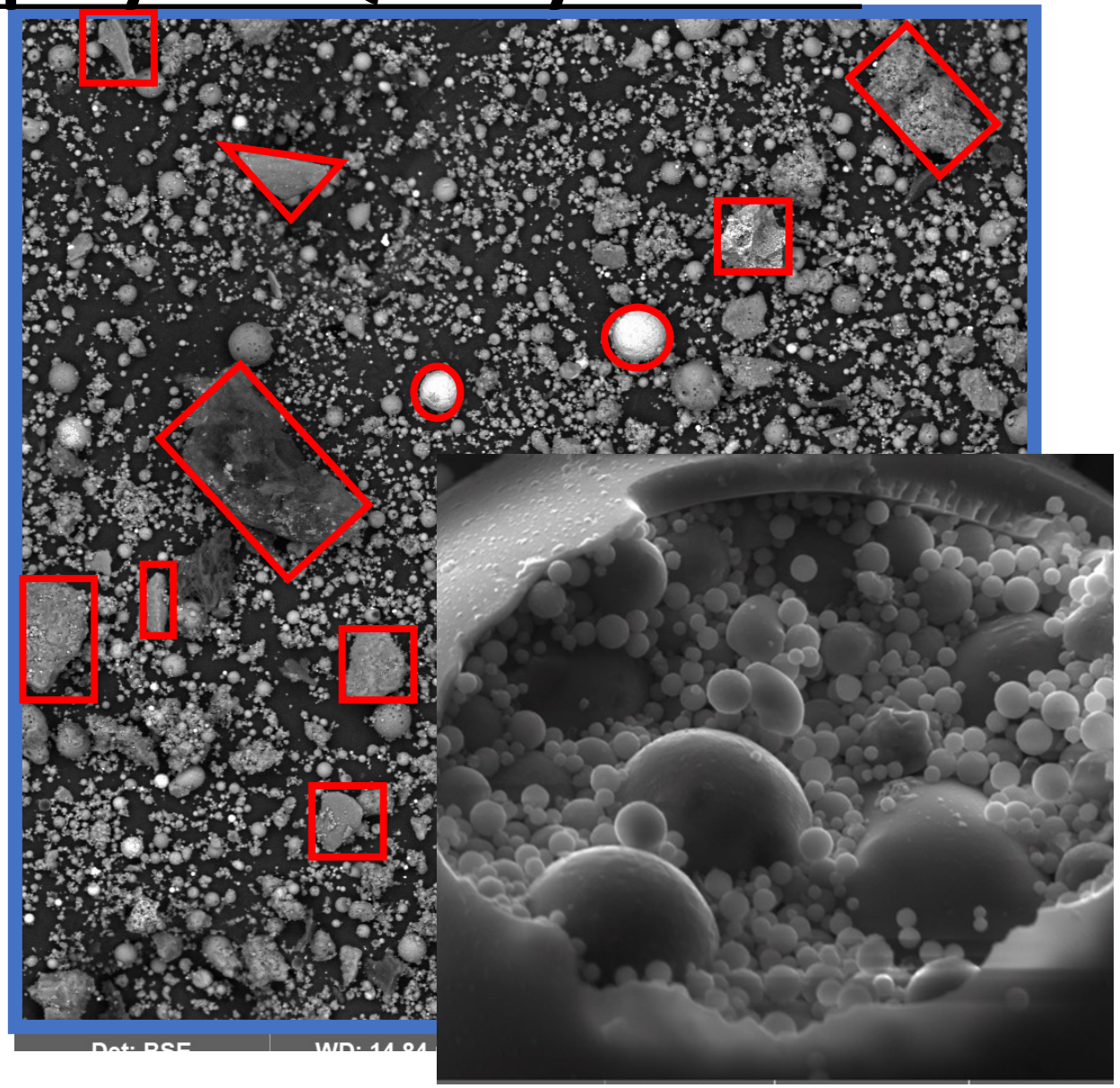
Major Learnings:

- Competitive Market Pressure
- Local Business Relationships
- **Quality Assurance & Quality Control**

Project Spotlight 1: Fly Ash Geopolymer Quality Control

Feedstock and Product QAQC & Mix Designing

- Various composition classifications of feedstocks can be quantified and used in mix designing to produce geopolymers, these include:
  - Bulk Composition (XRF).
  - Crystalline Composition (XRD).
  - Amorphous Composition ("XRF – XRD").
- Little work has been done to quantify what the *reactive* composition of a non-ideal geopolymer feedstock is that also encompasses the availability of the amorphous feedstock.
- "Reactive" mix designing can be done to produce consistent and optimised geopolymers. This presentation provides a very simplified overview.



Project Spotlight 1: Fly Ash Geopolymer Quality Control

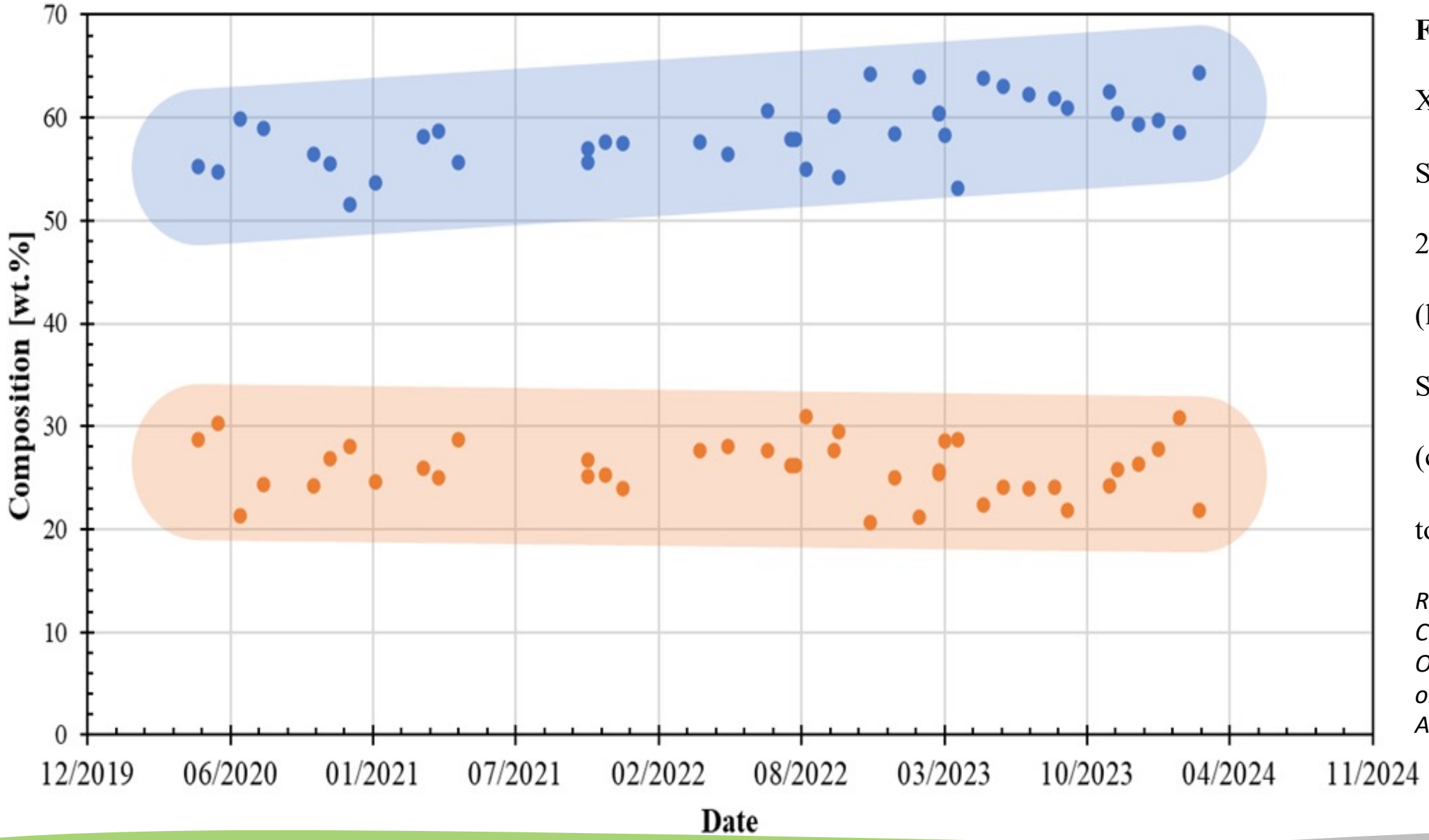


Figure 1a: Processed fly ash XRF data from Muja Power Station in Collie between 2020 to the present study (last data point) with (a) SiO2 and Al2O3 oxide (coloured regions displayed to infer bulk trends).

Ref: Skane et. al. Compositional Shifts in Fly Ash Over a Decade and its effect on Geopolymer Properties. ArXIV (Pre-Submission)

Project Spotlight 1: Fly Ash Geopolymer Quality Control

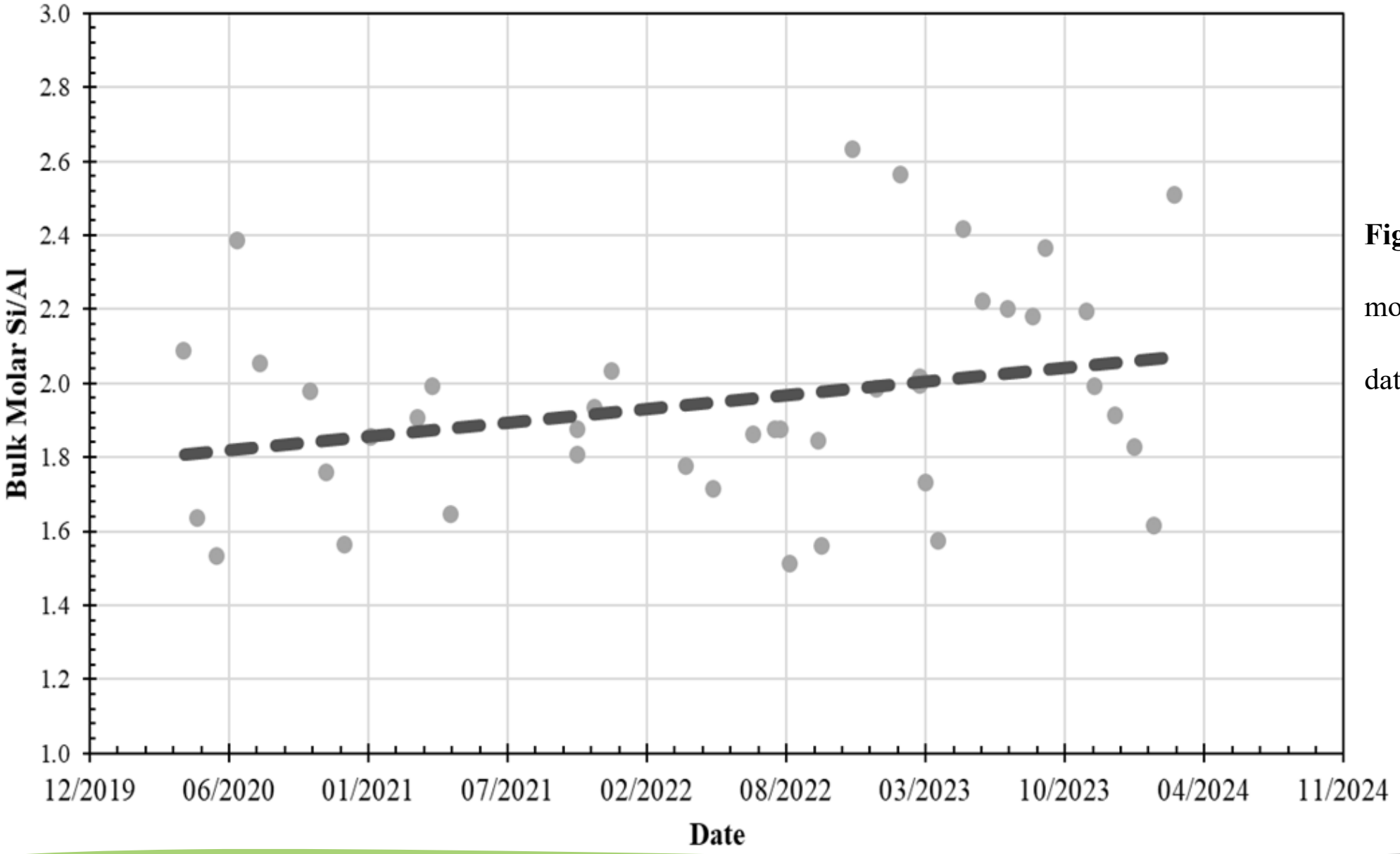


Figure 1b: Processed bulk molar Si/Al ratios. Original data from Fly Ash Australia.

Ref: Skane et. al. Compositional Shifts in Fly Ash Over a Decade and its effect on Geopolymer Properties. ArXIV (Pre-Submission)

Project Spotlight 1: Fly Ash Geopolymer Quality Control

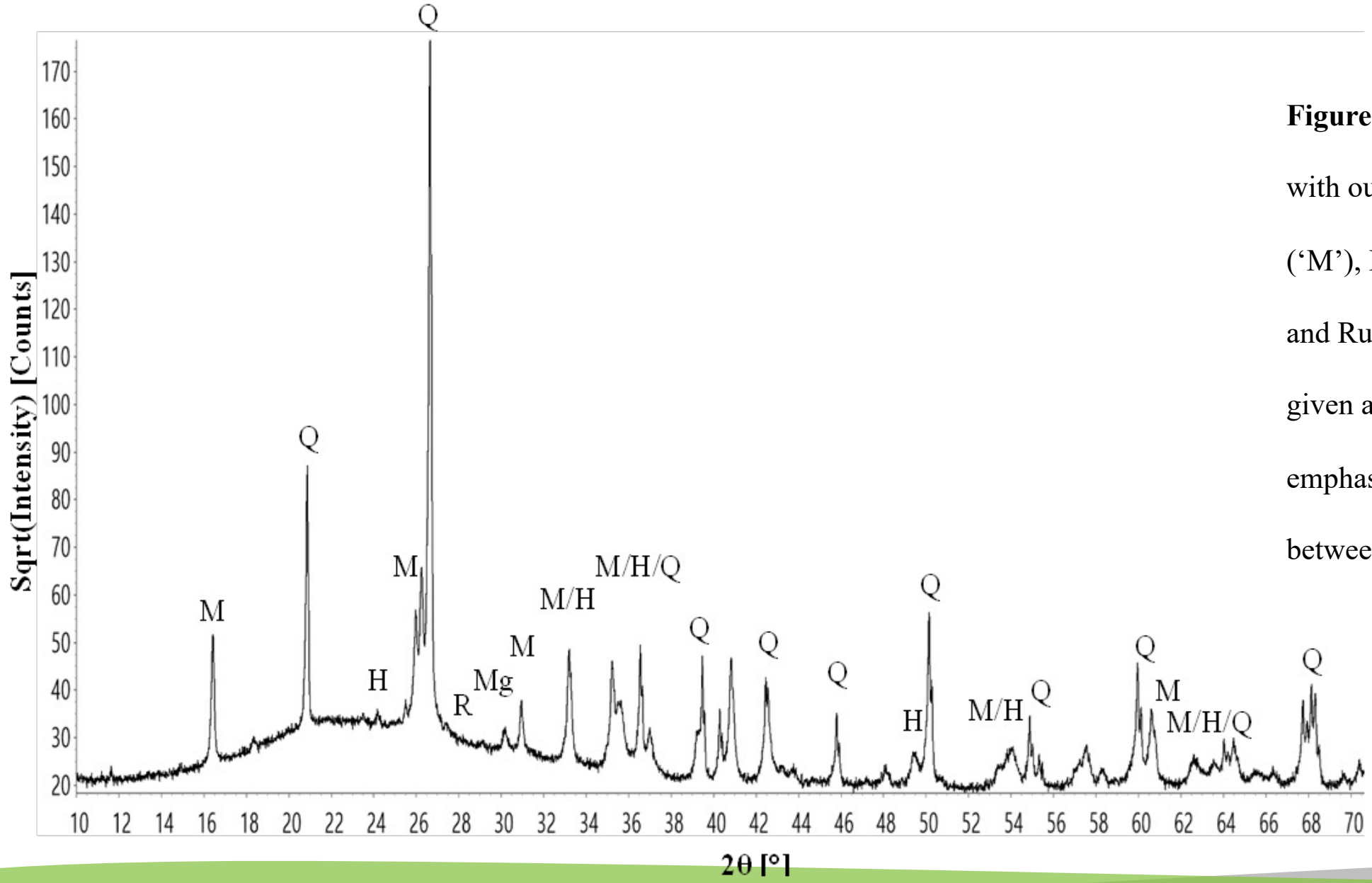


Figure 2: XRD pattern of the raw fly ash with outlined Quartz ('Q'), Mullite ('M'), Hematite ('H'), Magnetite ('Mg') and Rutile ('R') crystallites. Intensity is given as a square root function to emphasise the amorphous humps in between 15 - 35° 2θ .

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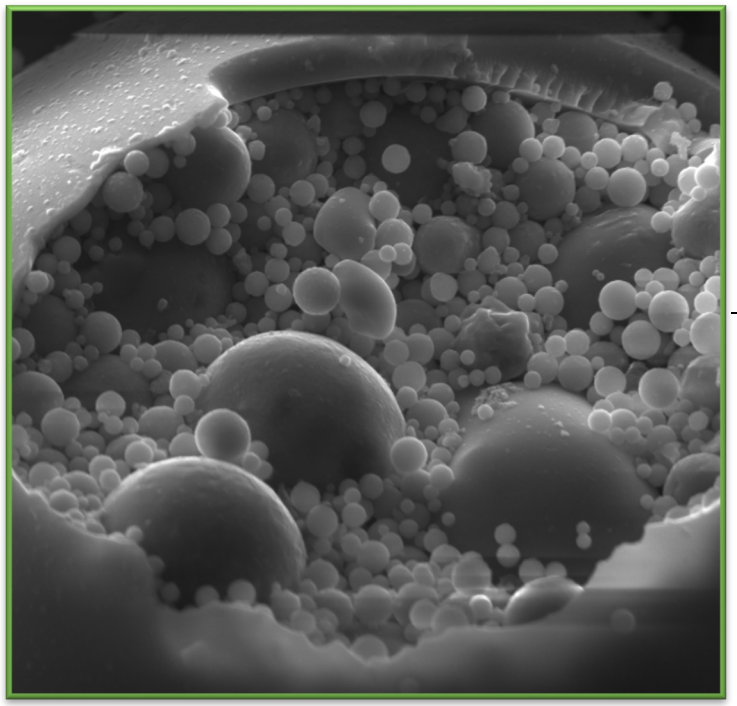
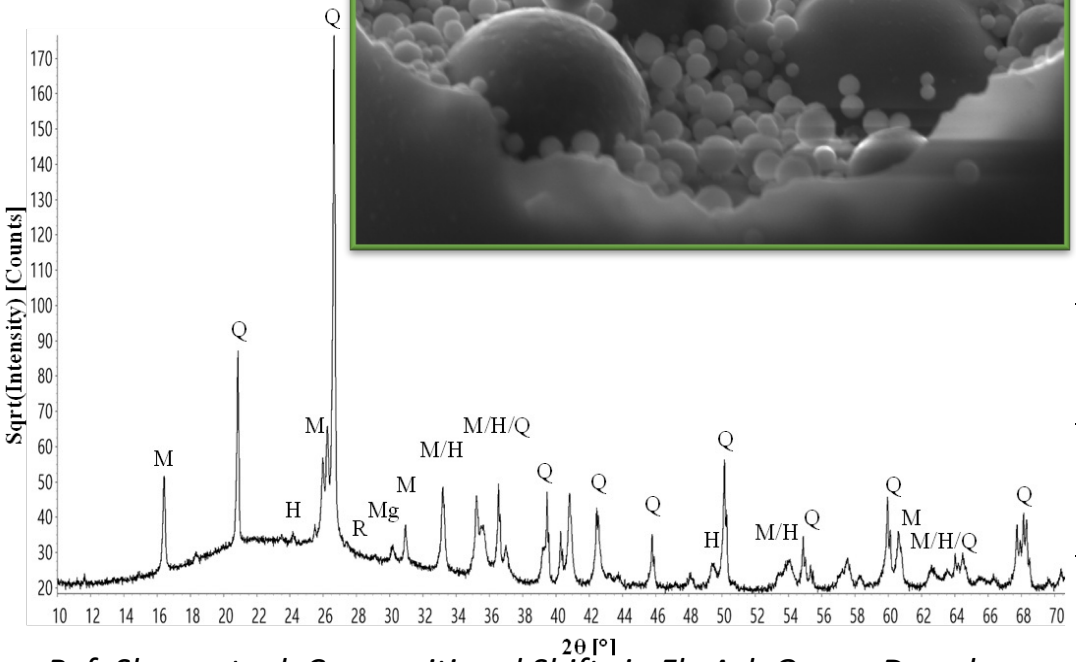
Project Spotlight 1: Fly Ash Geopolymer Quality Control





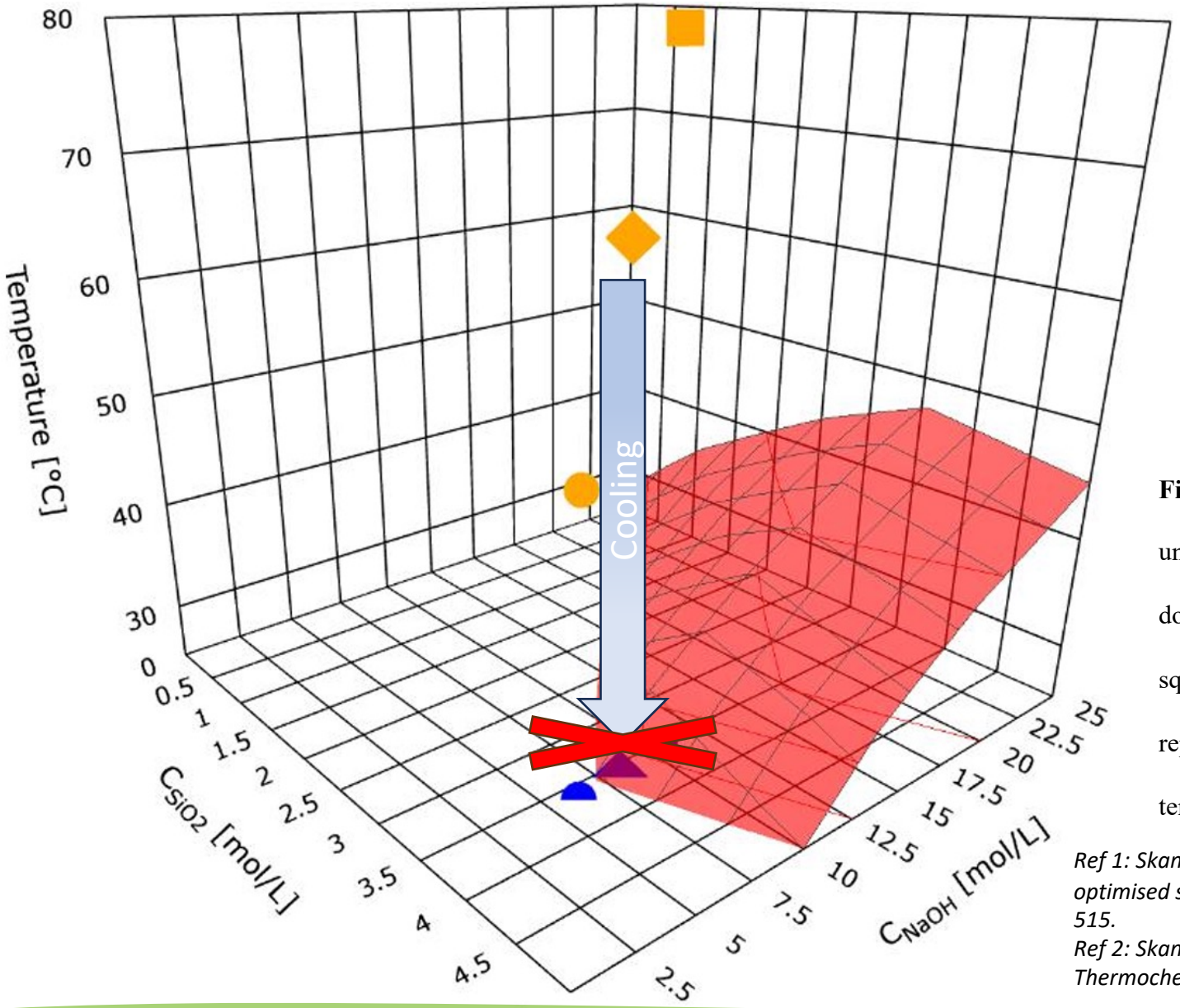
Ref: Skane et. al. Compositional Shifts in Fly Ash Over a Decade and its effect on Geopolymer Properties. ArXIV (Pre-Submission)

Table 3: Quantitative Phase Analysis (QPA) results detailing the crystallographic composition and amorphous characterisation of the fly ash precursors over time. Standard uncertainties (s.u.) of reported values are parenthesised.

	Parameter	Collie Fly Ash			[Units] (s.u.)
		This Study (2023)*	Rickard et al. (2009)* [9]	Williams & van Riessen (2007)* [24]	
Crystallographic Composition	α-Quartz	19.8(1)	15.05(21)	7.2(11)	[wt.%]
	Quartz (secondary)	5.1(1)	11.14(18)	9.0(11)	
	Mullite	21.2(2)	15.80(18)	13.7(11)	
	Hematite	1.7(1)	1.50(64)	1.9(2)	
	Magnetite	0.25(2)	2.51(83)	1.0(5)	
	Maghemite	-	-	1.85(8)	
	Rutile	0.00(3)	-	-	
	Amorphous	52.0(3)	54.00(45)	64(4)	
Other QPA Characterisation Results	Mullite *x* Parameter	0.273(3)	-	0.32	[-]
Amorphous Characterisation	Aluminosilicates (Oxides)	48.5(3)	36.29(77)	48.0(4)	[wt.%]
	Si/Al (Molar)	2.5(2)	1.15(4)	1.7(2)	[-]

** Dates refer to the year in which the referenced fly ash was sourced, as confirmed with authors of the respective publication. This value should not be conflated with the publication year of the cited work*

Project Spotlight 1: Alkaline Reagent Quality Control



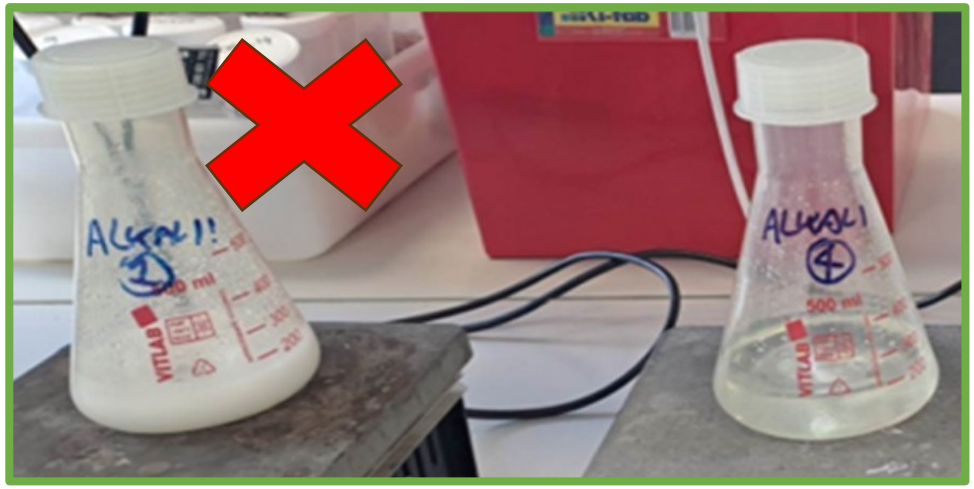


Figure 3: Activator solution stability solution space conveying metastable and unstable regions partitioned by the unstable ("US", red) hypersurface. Centred dot points representing the A, C and E experimental solutions plotted as squares, diamonds and circles where the orange and blue coloured icons represent the sodium silicate stabilisation (i.e. T_{Stable}) and ambient 25°C temperatures, respectively.

Ref 1: Skane et. al. 2025. "Predicting the stability of geopolymer activator solutions for optimised synthesis through thermodynamic modelling", Chemical Engineering Journal, Volume 515.

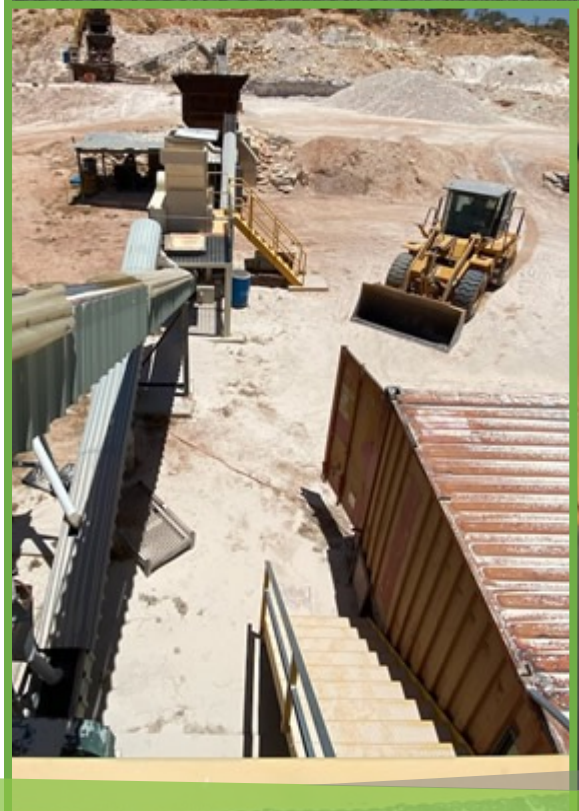
Ref 2: Skane et. al. "Optimisation of Activator Solutions for Geopolymer Synthesis: Thermochemical Stability, Sequencing, and Standardisation", [Pre-print], arXiv:2506.12941

Major Learnings: Large-Scale Trial Comparisons & QAQC

- Competitive Market Pressure.
- Local Business Relationships.
- Laboratory vs. Field
  - Compressive Strengths
  - Workability
  - Efflorescence
- **Quality Assurance & Quality Control**
  - Si/Al and Na/Al Molar Ratios, design vs practice
  - Alkaline Reagent Process & Production Efficiency. No requirement for 24+ hour stabilisation period required.

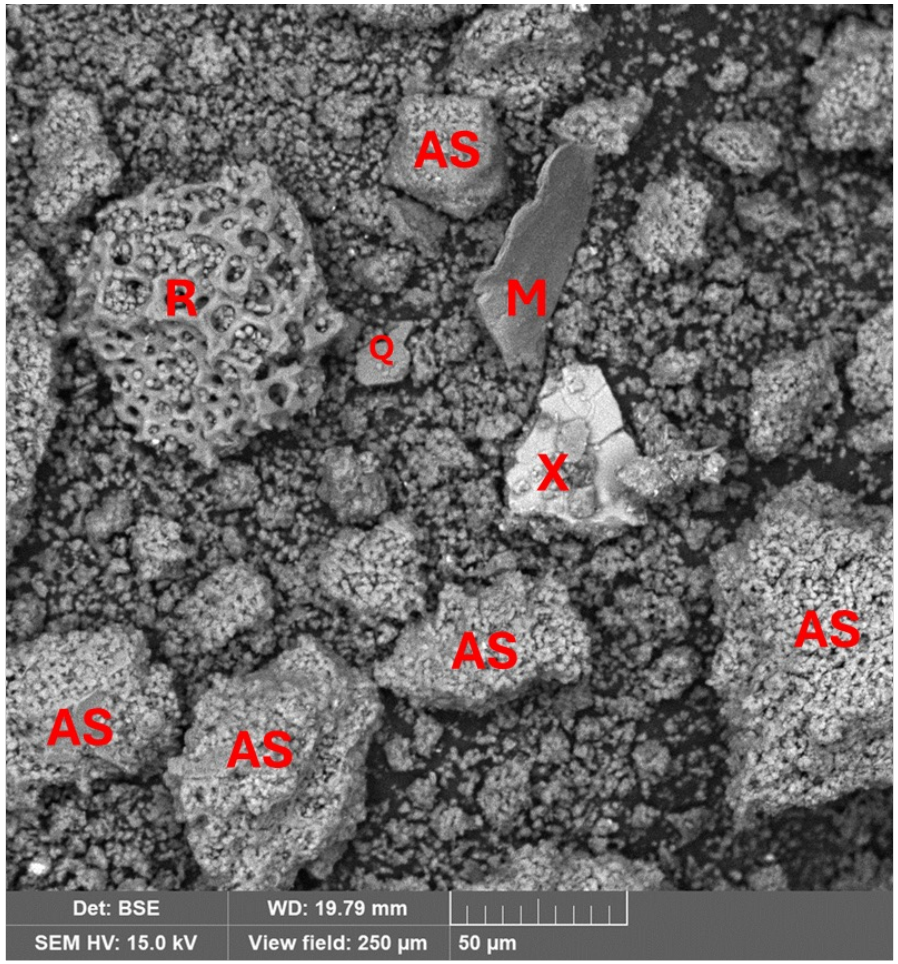
Project Spotlight 2: Amorphous Silica "Amsil" Opportunities

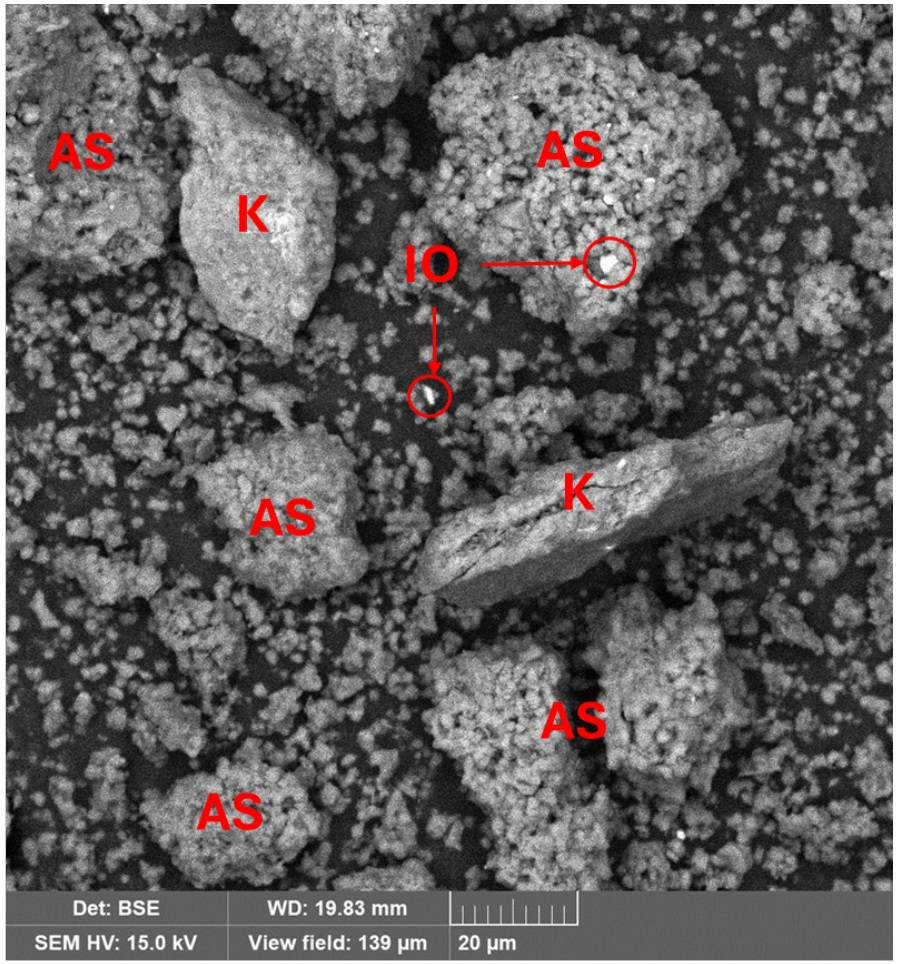
- Pioneering work in a opal-based Amorphous silica material.
- Silica materials have a big benefit in the cement, concrete and agricultural industries which RFMX is developing.
- Commercial Opportunities include:
  - Feedstock Supply Middleman to third parties.
  - Production of Silica-based Eco-Concretes.
  - Chemical Reagents



Project Spotlight 2: Amorphous Silica "Amsil" Opportunities

Figure 4: 250µm view field SEM Comparison between AS-UF and AS-12 Samples and qualitative crystallites



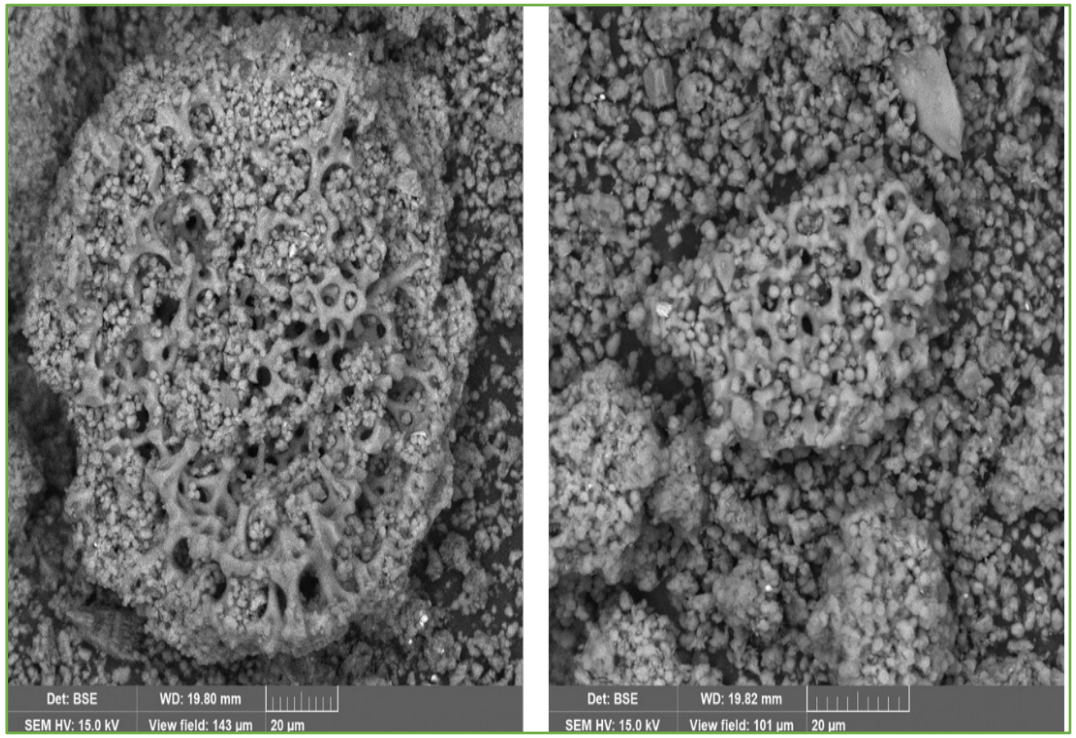


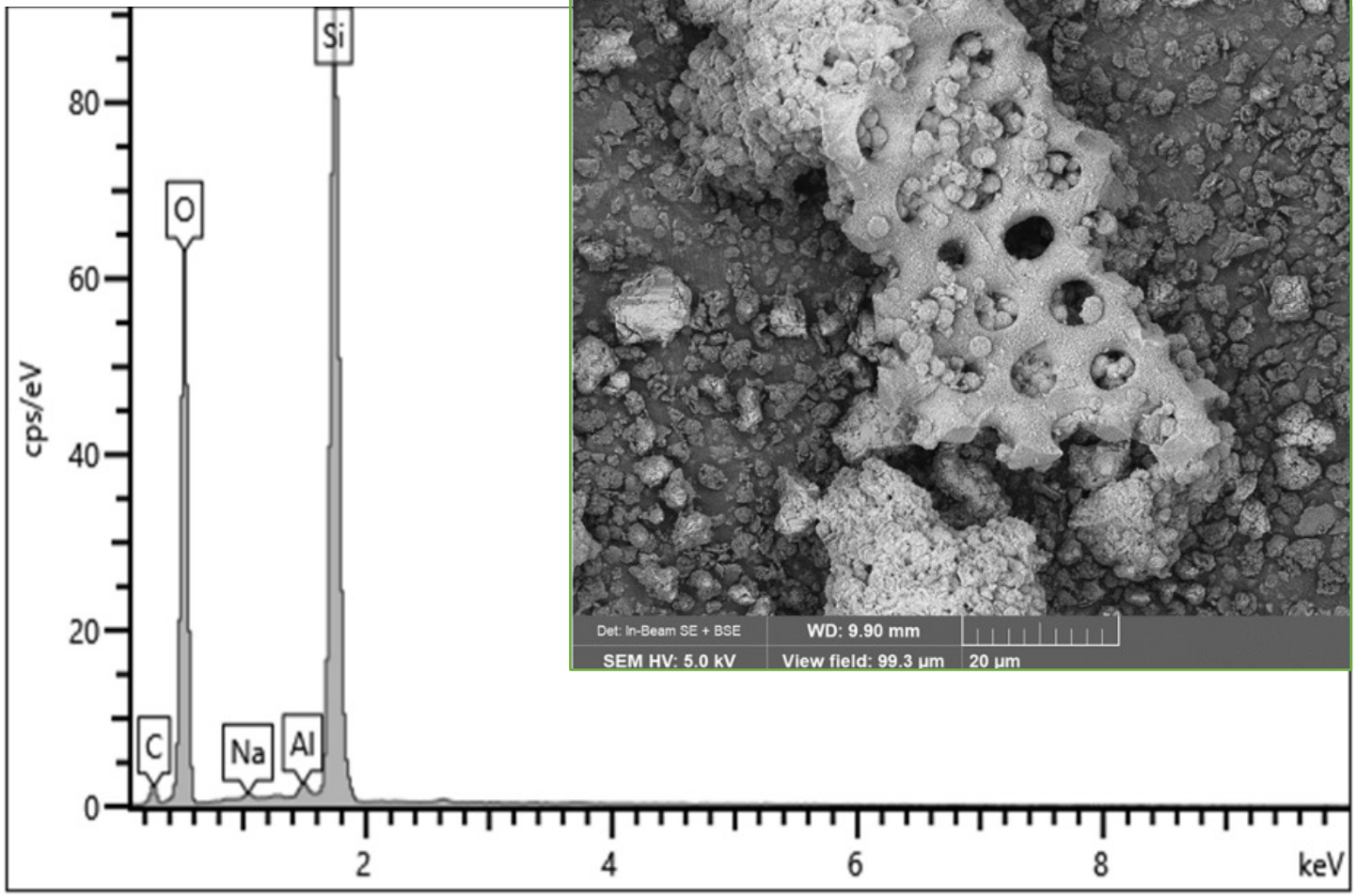
	Analyte	Value	
Bulk Composition	Al_2O_3	7.8(1)	[wt.% (s.u.)]
	BaO	0.0200(2)	
	CaO	0.68(1)	
	Cr_2O_3	0.0100(1)	
	Fe_2O_3	0.91(1)	
	K_2O	0.250(3)	
	MgO	0.230(2)	
	Na_2O	0.58(1)	
	P_2O_5	0.0370(1)	
	SO_3	0.070(1)	
	SiO_2	84.3(8)	
	TiO_2	0.410(4)	
	Loss on Ignition	4.26(4)	
	Total	100.0(10)	

A = Amorphous Silica
M = Muscovite
R = Radiolarian skeleton
Q = Quartz
K = Kaolin
IO = Iron Oxide
X = Mg, K, Fe Oxide.

Project Spotlight 2: Amorphous Silica "Amsil" Opportunities

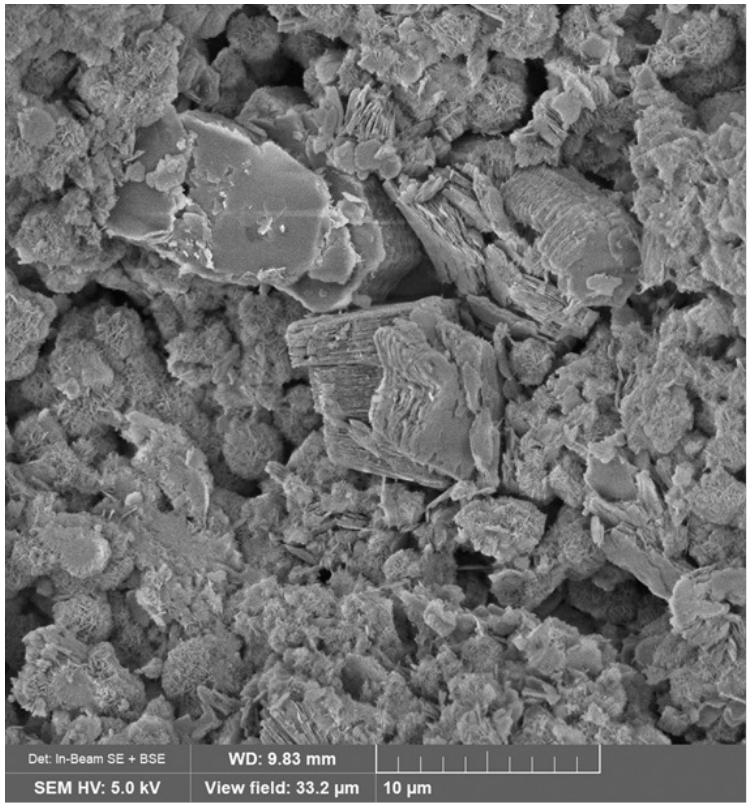
Figure 5: SEM & EDS Analysis of Radiolaria Skeleton / Biogenic Silica Material

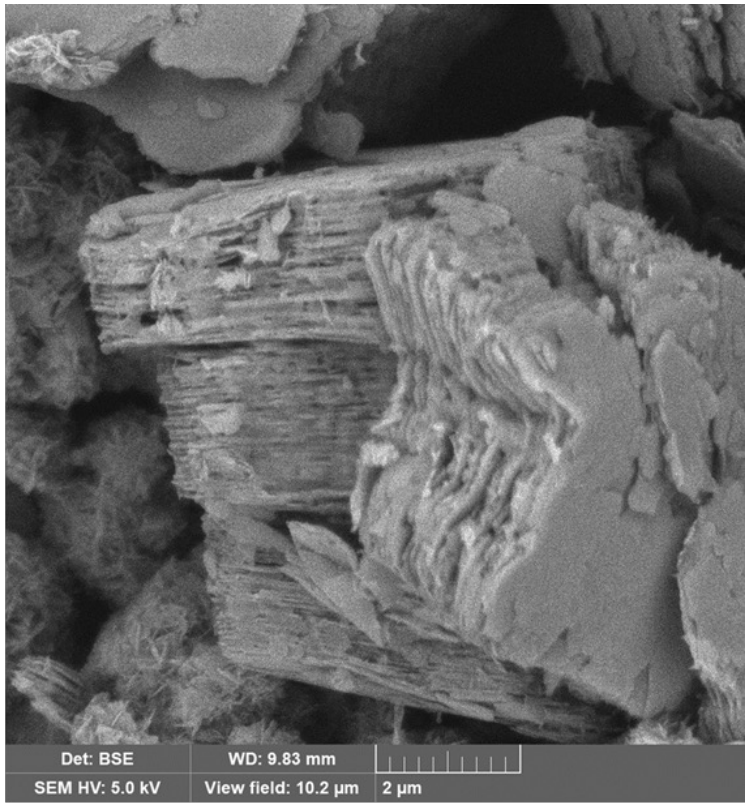


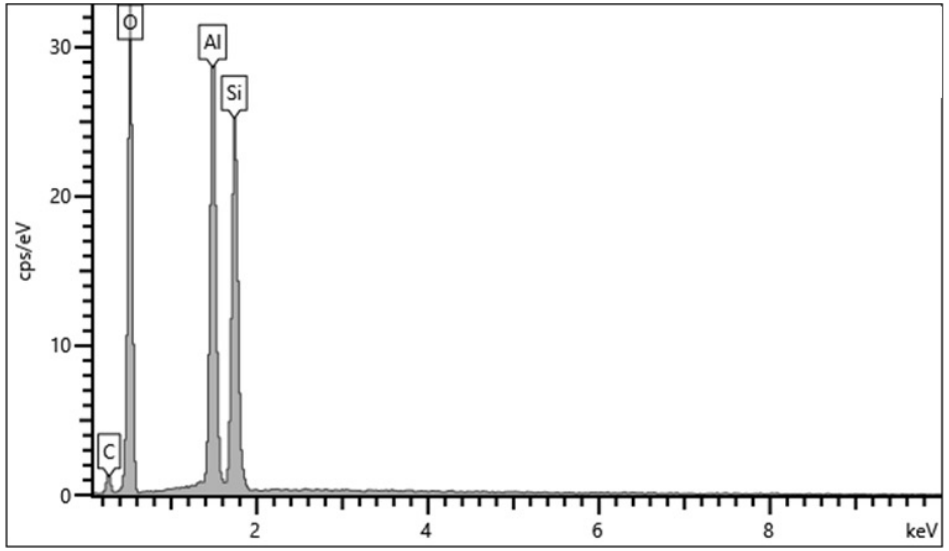


Project Spotlight 2: Amorphous Silica "Amsil" Opportunities

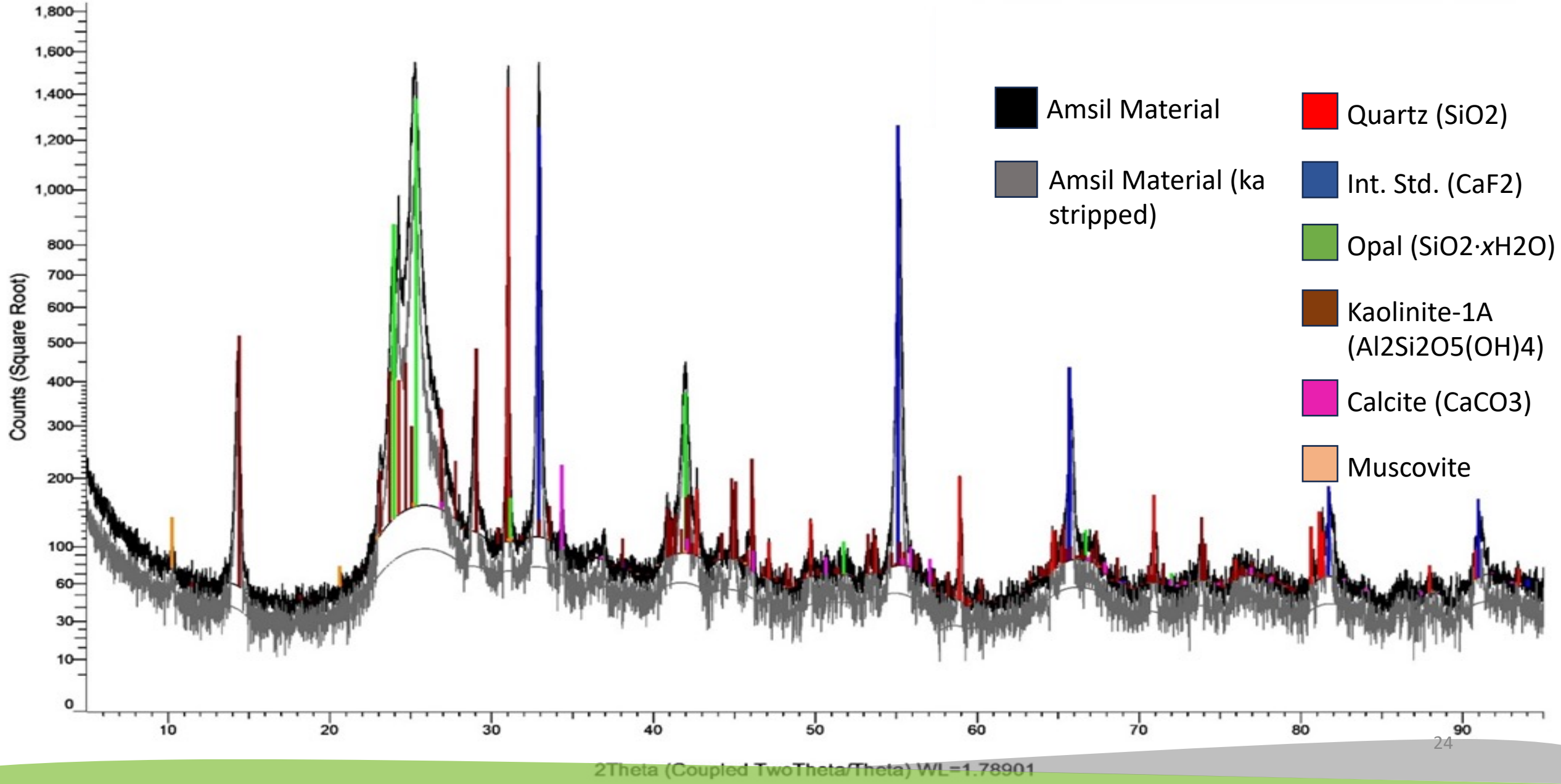
Figure 6: SEM & EDS Analysis of Kaolinite Material







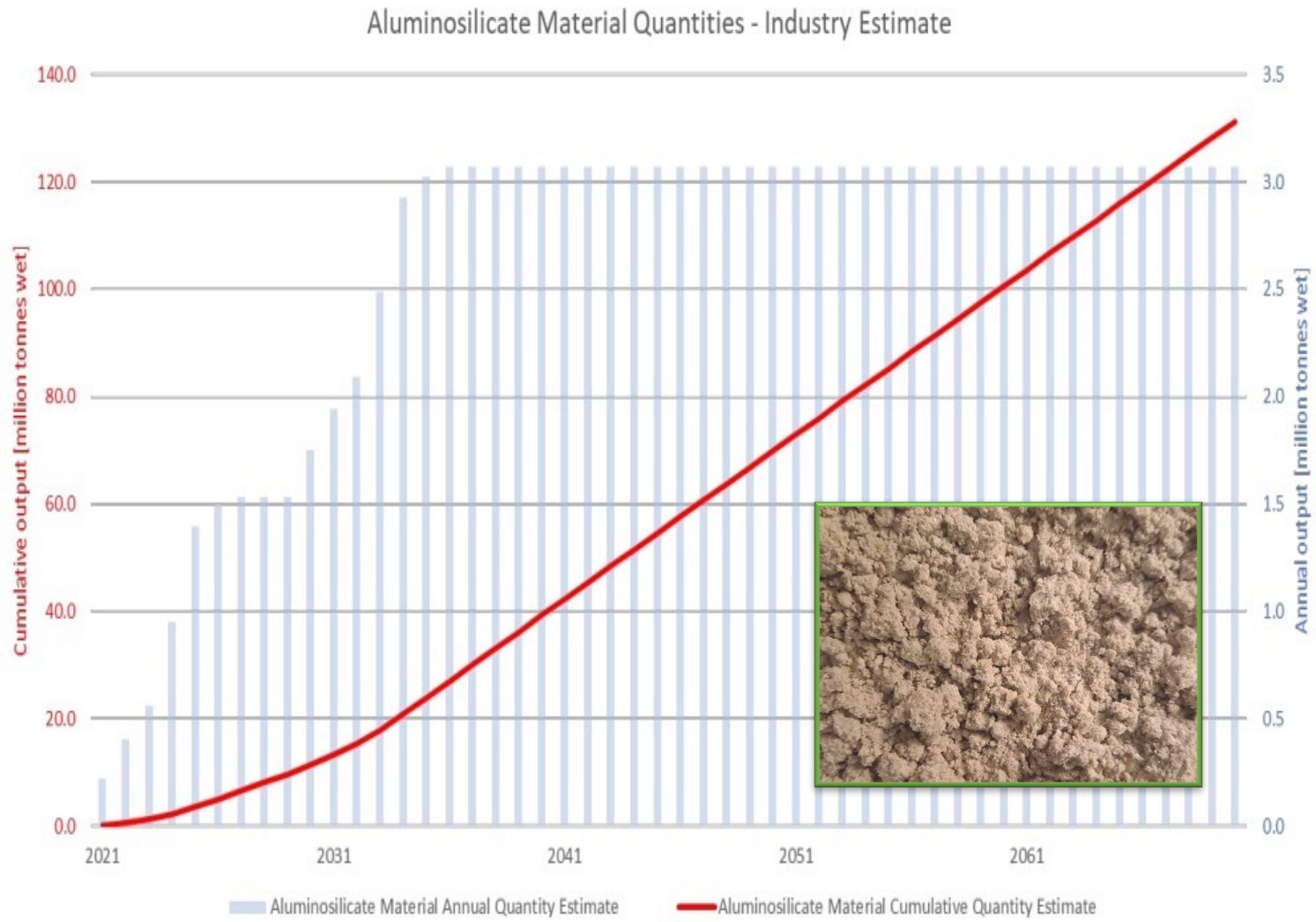
Project Spotlight 2: Amorphous Silica "Amsil" Opportunities



Project Spotlight 3: Other Mine Tailings

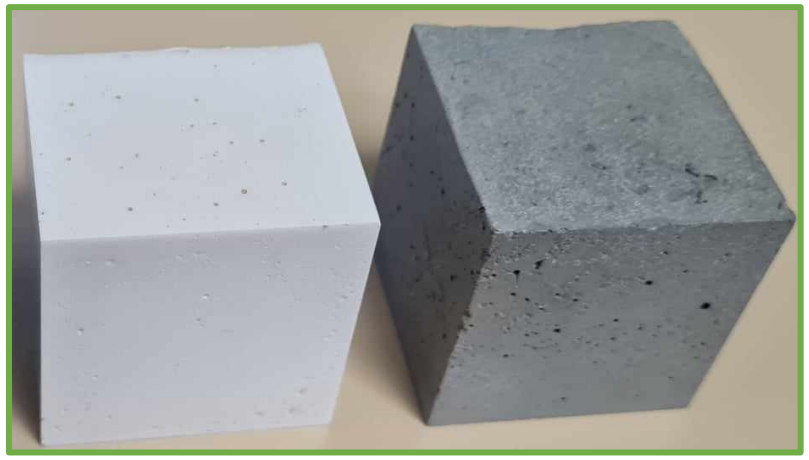
Some Industry by-products from the W.A. Mining Industry include:

- Lithium Aluminosilicate Residue (LASR).
- Nickel Mining Processing Materials.
- Iron Ore Processing Materials.
- Alumina Industry Processing Materials.



Ref: J. Casella and M. Olivares, "The Western Australian Lithium Industry - Enabling new and sustainable products beyond lithium chemicals," in Infrastucture Sustainablity Council (ISC) Annual Western Australia Sustainable Infrastructure Symposium, Perth, Western Australia, 2021.

Some Other Project Experiences

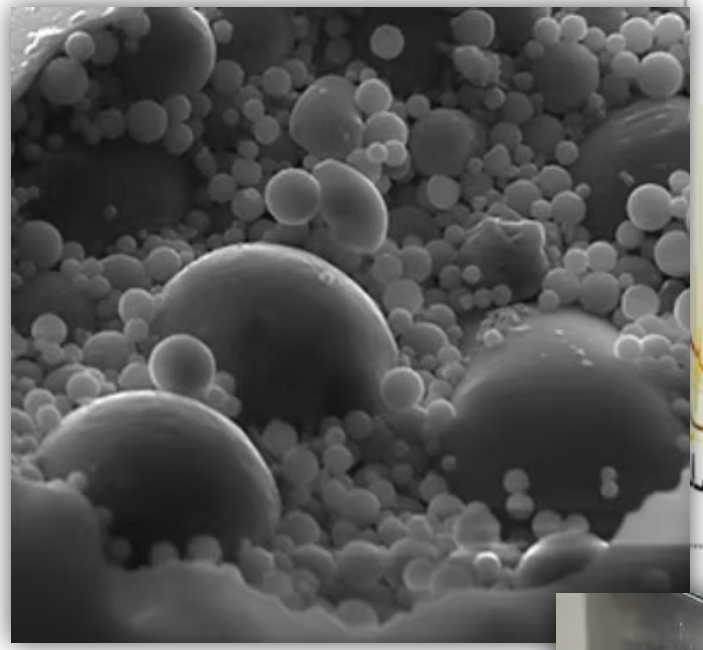


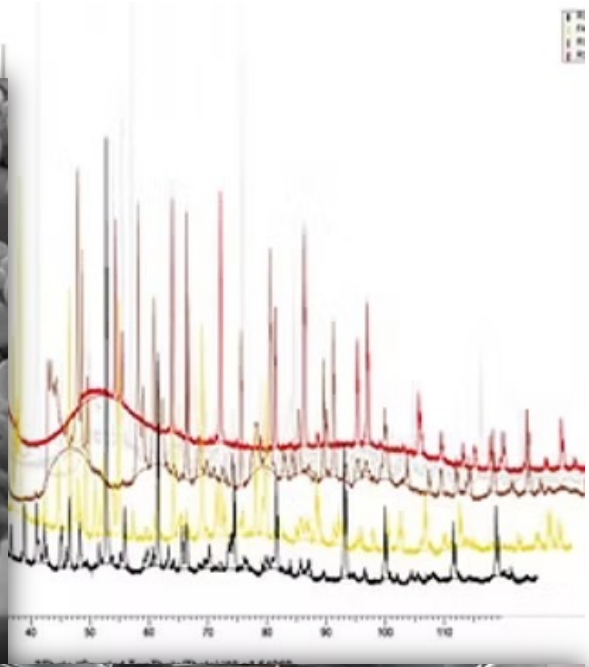
Reformix™
Materials Group

Our Products & Services

Our Products:-

- ✓ **Aluminosilicate Materials**:
  Fly Ashes, kaolins, metakaolins, amorphous silica and more.
- ✓ **Eco-Concrete** (Geopolymer): The Best Sustainable Concrete Alternative made from our signature Geopolymer Cement (Eco-Cement) product, synthesised almost entirely from industrial By-Products.
- ✓ **Eco-Portland Concrete**: Concrete made from a mixture of Conventional Portland Cement and Industrial By-Products, known as supplementary cementitious materials.





Our Services:-

- ✓ **Industry By-product Material Characterisation:** Offering expert consulting and testing in X-Ray analysis techniques, Mechanical Strength, Electron Microscopy and much more for all your material characterisation needs to transform your industrial *by-product* into a commercial *product*!
- ✓ **Life Cycle Assessments and Material Sustainability Consulting.**
- ✓ **Expertise Consulting:** Supply of key resources and expertise in engineering and materials science as an independent advisor to ensure project success.

Reformix™ Materials Group

Thankyou!

For collaborations or more information visit https://reformix.com.au/ or contact:

ramon.skane@reformix.com.au

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