POTENSI BASAL INDONESIA UNTUK PENYIMPANAN CO_2

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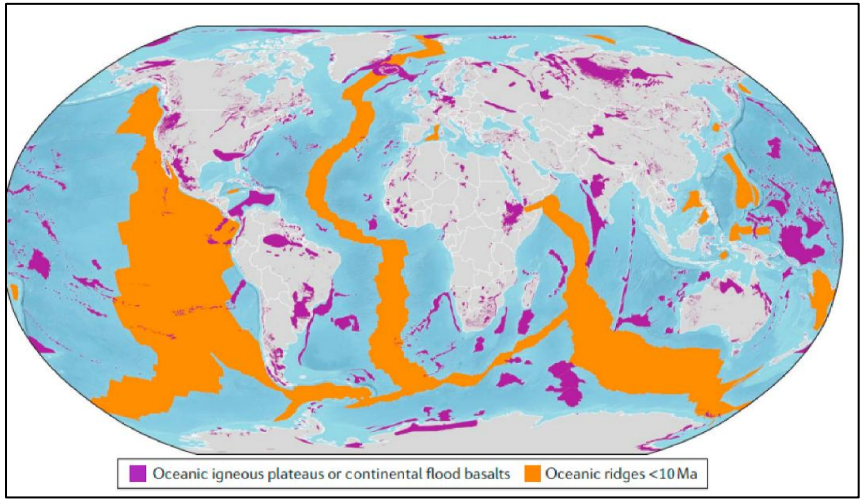
PENDAHULUAN

- Batuan **basal** merupakan jenis batuan beku yang membentuk 67% lapisan batuan dasar laut dan menyelimuti 10% permukaan benua (Gislason dkk., 2010; Hosseini dkk., 2022b, 2022a; Roex, n.d.).
- Formasi batuan basal dapat membentuk lapisan aquifer dan *aktivitas hydrothermal* (Eidesgaard dkk., 2019; Khadri dan Moharir, 2016; Möller dkk., 2016; Ystroem dkk., 2020).
- Pada penyimpanan karbon, batuan basal telah dianggap sebagai batuan yang menjanjikan untuk menjadi batuan *host* karena memiliki resiko kebocoran yang lebih rendah melalui proses mineralisasi dari pembentukan mineral sekunder (Goldberg dkk., 2008; Kelemen dan Matter, 2008; Matter dkk., 2007; McGrail dkk., 2006; Oelkers dkk., 2008)



Distribusi batuan basal (Snæbjörnsdóttir dkk., 2020)

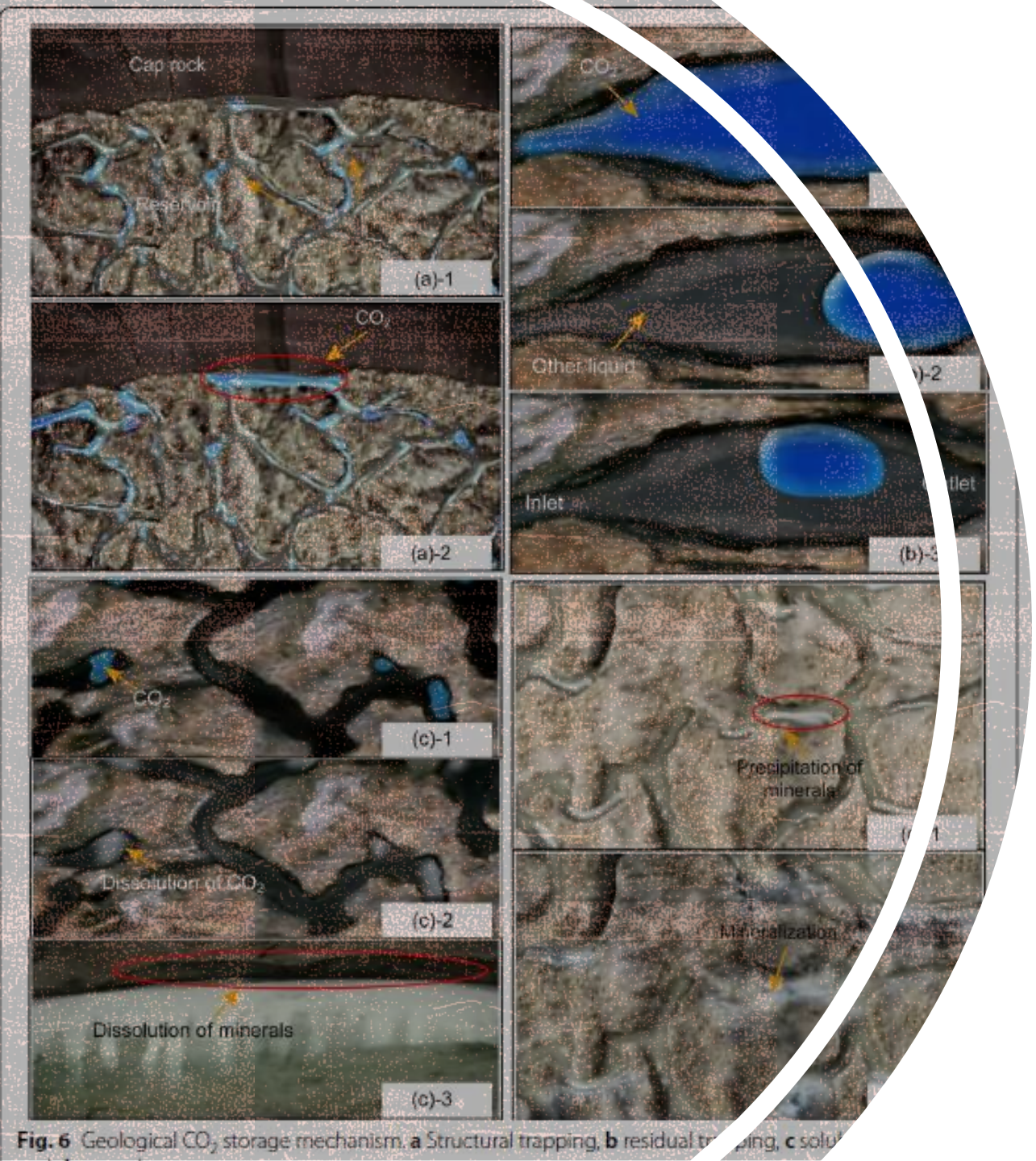


Fig. 6 Geological CO_2 storage mechanism. **a** Structural trapping, **b** residual tr ping, **c** solu

PENYIMPANAN CO2

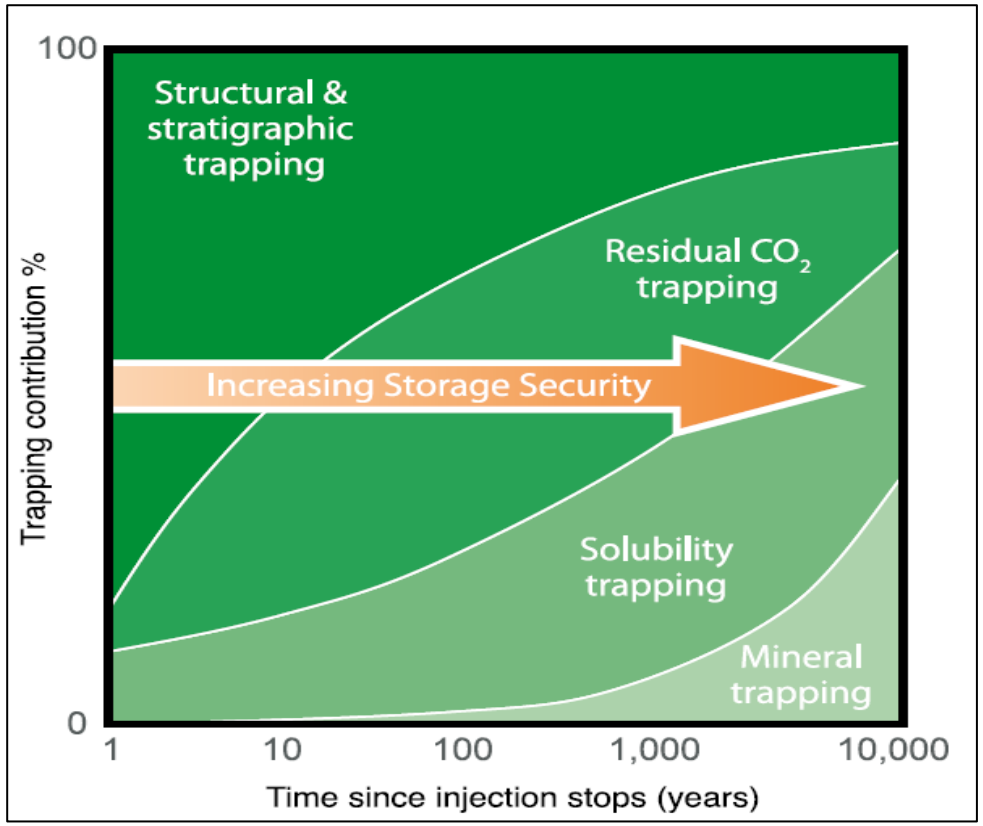
- **Snæbjörnsdóttir dkk., 2014** menjabarkan, terdapat empat mekanisme penyimpangan CO_2 dalam suatu formasi geologi. Mulai dari *structural trapping, residual trapping, solubility trapping,* hingga *mineral trapping.*

- **Oelkers dkk., 2008** mengemukakan bahwa mekanisme penyimpanan karbon ke dalam formasi batuan yang paling stabil dan berjangka panjang adalah pembentukan mineral karbonat, serta publikasi dari proyek injeksi CO_2 ke dalam batuan basal di Iceland, yaitu CarbFix.

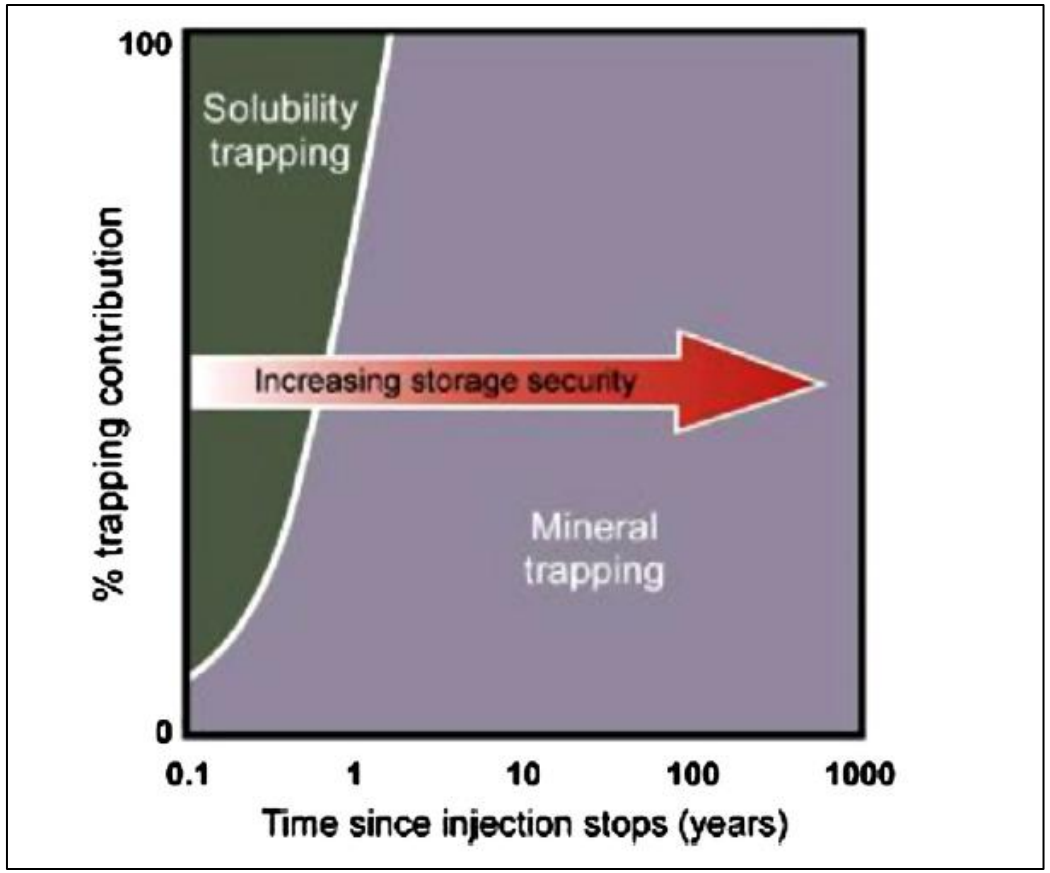
- **Matter dkk., 2011** melakukan penelitian pada batuan basal. Dimana ditemukan bahwa batu **basal mengandung mineral silica seperti Ca dan Mg, sehingga memiliki potensi mineralisasi yang tinggi** karena proporsi tinggi dari molar kation divalent (Xu dkk., 2004).

PENYIMPANAN CO2

- **Sigfusson dkk., 2015** mengemukakan bahwa pada penyimpanan CO2 ke dalam formasi basal, s*olubility trapping* terjadi dalam waktu 5 menit selama proses injeksi CO_2



Ilustrasi jenis mekanisme penyimpanan karbon terhadap waktu dari (S. Benson dkk., 2005)



Ilustrasi jenis mekanisme penyimpanan karbon pada formasi basal terhadap waktu (Snæbjörnsdóttir dkk., 2014)

FORMASI BASAL

- **Basal** merupakan batuan beku halus berwarna gelap yang sebagian besar terdiri dari mineral piroksen dan plagioklas, disertai dengan sejumlah kecil mineral seperti olivin yang terbentuk setelah pendinginan lava secara cepat di atau dekat permukaan bumi (Lu dkk., 2024).

Untuk mengetahui jenis basalt dapat digunakan TAS Diagram

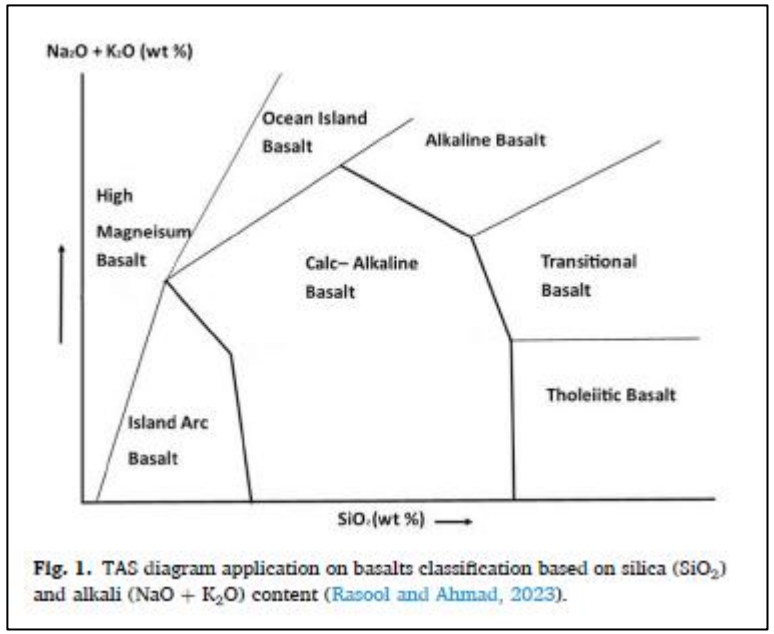
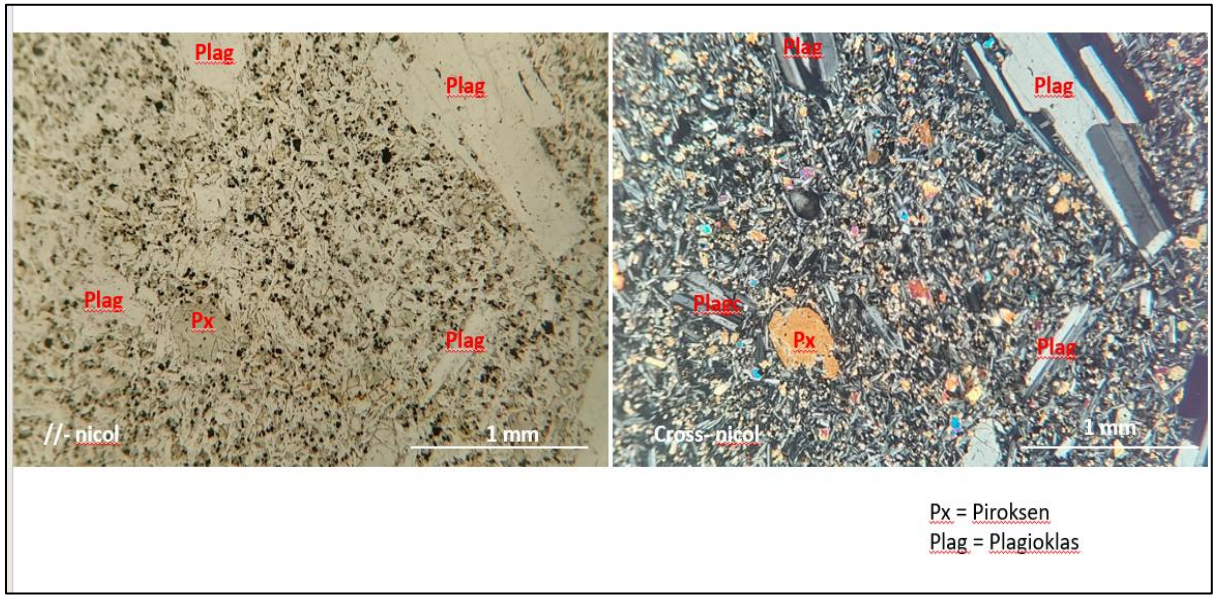
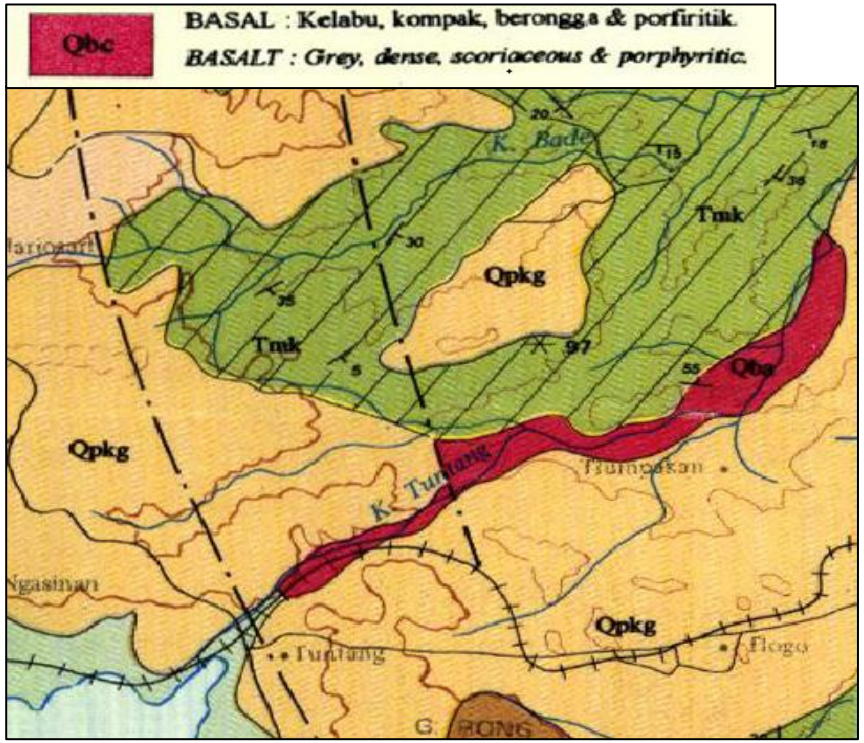


Fig. 1. TAS diagram application on basalts classification based on silica (SiO_2) and alkali ($NaO + K_2O$) content (Rasool and Ahmad, 2023).

SAMPEL BASAL INDONESIA

- Sampel batuan basal yang diambil dari berasal singkapan formasi basal magelang.
- Untuk melakukan validasi terhadap sampel batuan, dilakukan analisis sayatan batuan.
- Dari hasil sayatan batuan, dapat dikonfirmasi bahwa sampel merupakan jenis batuan basal karena memiliki mineral utama Plaglioklas sebesar 68%.





JENIS BASAL MAGELANG

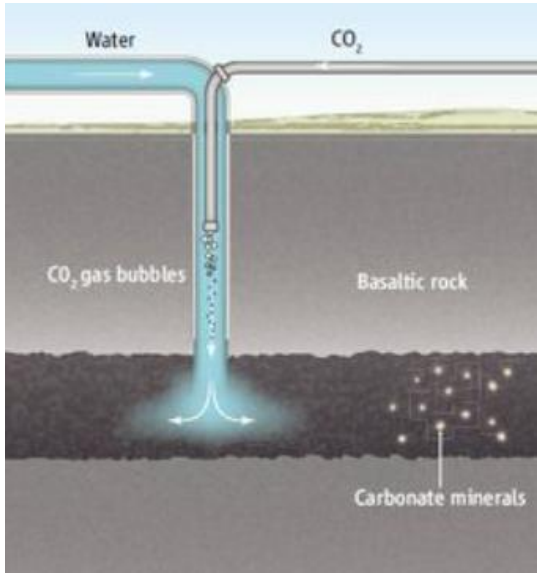
PENGUJIAN MINERAL PENYUSUN BASAL DILAKUKAN UNTUK MENGETAHUI JENIS BASAL YANG DIGUNAKAN PADA PENELITIAN

DARI HASIL PENGUJIAN XRD SAMPEL BATUAN BASAL TERDIRI ATAS MINERAL UTAMA **FELDSPAR ALBITE SEBESAR 53,76%.**

BERDASARKAN KATEGORI BASAL OLEH RASOOL AND AHMAD, 2023 SAMPEL BASAL TERSEBUT KEMUNGKINAN BESAR TERMASUK KE DALAM *ISLAND ARC BASALT*. DIMANA BASAL JENIS INI MEMILIKI CIRI KANDUNGAN PLAGLIOKLAS FELDSPAR ANTARA 30-60%.

Sampel	Quartz (%)	Calcite (%)	Clay (%)	Mineral Lain						
				Feldspar (%)	Pyrite (%)	Dolomite (%)	Sillimanite (%)	Epidote (%)	Hornblende Magnesio (%)	Cristobalite (%)
Basal	2.14	6.61	12.36	53.76	1.86	2.49	2.66	7.41	6.19	4.51

POTENSI FORMASI BASALT INDONESIA UNTUK PENYIMPANAN KARBON



1. FORMASI BASALT CARBFIX, ICELAND

- University of Iceland, Reykjavik Energy, Iceland, University of Columbia, US, dan CNRS, Toulouse, Prancis bekerja sama dalam proyek penelitian, Carb-Fix, untuk mengoptimalkan metode penyimpanan CO2 dalam batuan basalt.
- Proyek ini terdiri dari CO2 terlarut dengan air pada skala lapangan ke dalam batuan basalt. Formasi batuan terdiri dari formasi hialoklastit basaltik dan aliran lava) Komposisi silika berkisar dari 45% hingga 49% SiO2.
- Hasil XRD sampel basal Iceland memiliki kandungan mineral utama **Labradorite 58.6% dan Augite 36.5%.**
- *Solubility trapping* terjadi dalam waktu 5 menit selama proses injeksi CO_2 (Sigfusson dkk., 2015), dan karena reaktivitas batuan basalt, sebagian besar karbon terperangkap dalam mineral dalam waktu dua tahun (Snæbjörnsdóttir, dkk., 2014).

Sample ID	Interstitial glass (Mesostasis)	Plagioclase feldspar	Pyroxene	Opaques (magnetite)	Total
			(wt%)		
CR	45.3	35.3	18.3	1.0	99.9
CAMP	30.7	43.3	26.0	<1.0	<101.0
NB	27.0	46.0	26.0	1.0	100.0
Deccan	20.7	48.7	29.3	1.3	100.0
Karoo	23.3	45.8	30.8	<1.0	<100.9

- Lima sampel basal, yaitu: CR, CAMP, NB, Deccan, dan Karoo diteliti untuk mengetahui bagaimana reaksi masing-masing sampel untuk proses mineralisasi.
- Perbedaan komposisi dalam endapan menunjukkan perubahan dalam kimia fluida yang unik untuk perilaku pelarutan setiap sampel basal yang bereaksi dengan air-CO2. Tidak ada korelasi yang cukup kuat yang ditemukan antara reaktivitas basal dan perbedaan dalam komposisi bulk, mineralogi, kuantitas atau komposisi mesostasis kaca.
- Selain itu, reaktivitas relatif dari sampel basal yang berbeda juga memberikan hasil yang berbeda dalam percobaan yang dilakukan dengan campuran CO2–H2S terlarut dalam air dibandingkan dengan yang hanya menggunakan CO2

2. SAMPEL BASALT US, INDIA, DAN SOUTH AFRICA (SCHAEF., ET.AL, 2010)

Composition of crystalline and glassy basalt from the Stapafell Mountain, obtained by XRF analysis.

Sample	SiO_2	Al_2O_3	Fe_2O_3[b]	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI	Total
Crystalline	47.9	13.4	12.3	10.0	12.2	1.5	0.3	1.6	0.2	0.2	−0.5	99.1
Glass[a]	48.1	14.6	10.9	9.1	11.8	2.0	0.3	1.6	0.2	0.2		98.8

3. CRYSTALLINE BASALT, SOUTHWEST ICELAND

- Gudbrandsson., et.al 2011 memberikan komposisi sampel basalt dari Stapafell Mountain, SW-Iceland
- Pada penelitian ini dilakukan pengamatan terhadap pelarutan dan pelepasan ion Ca, Mg, dan Fe yang berkaitan erat dengan proses mineralisasi

4. BASALT EASTERN SNAKE RIVER PLAIN, IDAHO, USA (LUHMANN ET AL 2016)

Empat percobaan aliran dilakukan pada inti basalt dari Eastern Snake River Plain, Idaho, USA menggunakan reaktor sistem aliran hidrotermal. basal tersebut terdiri dari komposisi berikut: **48,5% plagioklas, 13,8% olivin, 12,5% diopsida, 12,4% hipersten, 5,43% ilmenit, 4,71% ortoklas, 1,74% apatit, 1,13% magnetit, dan 0,09% zircon.**

Perubahan porositas, permeabilitas, dan luas permukaan yang disebabkan oleh interaksi fluida-batuan kaya CO2. Permeabilitas sedikit menurun selama percobaan laju aliran yang lebih rendah dan meningkat selama percobaan laju aliran yang lebih tinggi

5. BASALT NEW ZEALAND (HOSSEINI ET AL 2023)

Sampel basal new zealand mengandung labradorit ((Na,Ca)1-2Si3-2O8), augit (Ca(Fe,Mg) Si2O6), olivin ((Mg,Fe)2SiO_4), dan nefelin ((Na,K)AlSiO4) sebagai komponen mineral utama.

Pada penelitian ini sampel dilakukan pengukuran zeta potential yang berhubungan dengan perubahan wetting state basalt pada saat berinteraksi dengan fluida pada perubahan suhu, tekanan, dan pH.

Mineral phase	Composition (wt%)
Anorthite ($CaAl_2Si_2O_8$)	51
Augite [(Ca, Na) (Mg, Fe, Al, Ti) $(Si, Al)_2O_6$]	16
Albite ($NaAlSi_3O_8$)	33

- Pada percobaan column reactor, tinggi kolom CO2 dari basal SA murni lebih tinggi daripada yang dilaporkan untuk basal WA dan Iceland.
- Selanjutnya, pada suhu 323 K, tinggi kolom CO2 menurun dari 835 m pada tekanan 5 MPa menjadi 957 m pada tekanan 20 MPa.
- Hasil ini menunjukkan bahwa mungkin ada pergerakan CO2 yang lebih bebas secara vertikal dan lateral ke dalam basal SA pada kondisi asam organik, sehingga menghasilkan kapasitas penangkapan sisa dan mineral yang lebih rendah, dan lebih sedikit kebocoran CO2 pada akhirnya, melintasi formasi geologi.

6. BASALT HARRAT RAHAT, SAUDI ARABIA (ALI 2023)

Mineral	Chemical Formula	%
Albite	$NaAlSi_3O_8$	60.4
Quartz	SiO_2	22.6
Calcite	$CaCO_3$	1
Microcline	$KAlSi_3O_8$	6.4
Clinochlore	$Mg_5Al\ (AlSi_3O_{10})\ (OH)_8$	4.8
Pyroxene	$(Ca, Na, Fe^{2+}, Mg)\ (Cr, Al, Mg, Co, Mn, Sc, Ti, Fe^{2+})\ (Si, Al)_2O_6$	1.2
Anorthite	$CaAl_2SiO_8$	3.5

- Penelitian ini melakukan Eksperimen pengukuran *zeta potential* basal setelah adanya presipitasi Ca, Mg, dan Fe pada sampel *grounded* basal.
- Presipitasi karbonat memiliki efek signifikan pada permukaan batuan basal. Hanya dalam kasus MgCO3 dan FeCO3 dan bukan dalam kasus presipitasi CaCO3 presipitasi.

7. BASALT AL MADINAH, SAUDI (MOHAMMED 2024)

Secara umum, komposisi basalt Magelang yang memiliki mineral albite sebesar 53.7% dan dicirikan memiliki kandungan utama plagliokIas merupakan jenis basalt yang cukup potensial untuk dilakukan penelitian lebih lanjut agar dapat dikembangkan menjadi kandidat injeksi penyimpanan CO2 di Indonesia.

Meskipun, untuk dilakukan injeksi tentunya diperlukan penelitian untuk mengetahui besarnya formasi sebagai ruang untuk injeksi penyimpanan CO2. Selain itu, pada penelitian terdahulu dikemukakan bahwa perbedaan komposisi dan morfologi basalt akan mempengaruhi laju mineralisasi.

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