World music w/ research

World music: polite term for misc. music of the world. 1987 it (heavy dues to Jamaican music) became a marketing category (Empress of Russia Pub (in London))

as an academic field of study, musicology = study of western art music. (Anthropology + ethnomusicology) = study world music

ethnomusicology = study of people making music in/as culture (Titan) cross of musicology and anthropology

Culture: (dynamic) systems of learned behaviors across specific groups of people. (Raymond Williams 1958) high-low SES. how we think/what we do/how we do things - way of life has macro + micro groups. Ethnography — study culture by (fieldwork = participation/observation + interviews)

Globalization - how world circulation occurs. - interconnected w/ overlap in travel

- Homogenization - Cultural spin-out make it the same ex: McDonald's around world
- Indiginization - global facts take local forms ex: McDonald's in India is dif. than in U.S.

Research methods

Thick description - researcher interprets the "native" (interlocular) events.

use both Data [Emic (insider view) = natives not totally conscious of all their customs. = oblivious to obvious.
Etic (outsider view) = bias by researcher showing up w/ natives try to impress (over.) = the observer creates bias. ~~not totally natural.~~

Titan's 4-parts of music culture

- Ideas - belief system, shared aesthetics history & future proposition, context
- Activities - Secular v. non Secular, performance roles, style, audience interaction, historical context, events
- Repertories - genre's, what #/types of songs played/listened / how shared
- Material culture - instruments, rec. equipment, sound system, mp3's, environment

Merriam's 3-part model — sound, behavior, conception

Circulations in the Black Atlantic in Jamaica

Afro-deaspora - zone of interconnected streams ex: middle passage brought Africans to Jamaica

brief History

1494	1655	1834	1950's (mento)	1960's	1962	1966-7	1968	1970's-80's-now
Columbus claimed for Spain	Grt. Brit claimed to harvest sugarcane (cash crop)	slavery ends 1838 full emancipation	U.S. R+B to Jamaican R+B	Ska	independence from Grt. Brit	Rocksteady	reggae	Dancehall

Circulation in the black Atlantic - Jamaica

Genre

Mento — The Jolly Boys "Woman's Smarter" rural hills outside capital folk music. Rhumba box, banjo, guitar, vocals

Jazz big bands - used for tourists entertainment, musicians from ghetto trained from Alpha school (cath)

Sound Systems - liquor store used to draw crowds. (gathering spot) in ghettos, - community. lots of competition → kept song tracks secret
lots of bass usage. 1st time marginalized people had their own culture. ↳ music, pol., commerce, fashion, news, fun

U.S. R&B — Wynonie Harris "Blood shot Eyes" 1951 walking bass, accent on upbeat w/ clapping Jumpblues. mysoginistic lyrics

• New nat. identity • No like U.S. Rock'n'roll b/c aesthetic tastes • young people wanted to work w/ sound systems • talent (sing) shows w/ trained musicians (Alpha School)

Jamaican R&B — Sang & Harriott "Lollipop Girl" 1956 Jazzy g-solo doo-wop vocal backing bass heavy

Ska - 1960's similar but w/ diff rhythms. Ernest Ranglin - trained @ alpha school, Jazz musician

Rastafarianism - 1930 (reinterpret christianity deus as African) b/c ethiopia Blk. Ruler. Pol. + Rel. movement
1st Nyabingi 1958 Ska attend. - shunned/outcasts in Jamaica.

intermediate — The Folkes Brothers (singers) w Prince Buster (producer) & Count Ossie (Rasta-drummer) "Oh Carolina" 1960
mo' bass Prince Buster ahead of time to invite rasta drum circle

Ska - lots of people, double bass, piano, trapdrumset, guitar, back up singers / lead vocal

Ska — Derrick Morgan "Foward March" - 1962 military march drums, sax solo, happy b/c independence.
walking bass w/ accent on upbeat

Ska — The Wailing Wailers (early Bob Marley) "Simmer Down" - 1963 "classic" ska sound. post independence things got worse - looting / killing

Rocksteady (1966-7) "Golden age" for Jamaican music - couples dance - slower - less optimism Rude Boys - gangsters breasers w/ knives + guns

Rocksteady — Hopeton Lewis "Take it easy" 1966 bass mo' prominent + rhythm + palm muting guitar sounds mo' live Rude Boys reference.
instrumentation stripped down, mo' spacious new e-bass ostinato line. heavy rude boy reference

Rocksteady — Alton Ellis "Rocksteady" 1966 (instructional dance song) links btw dancers / musicians heavy reggae links

Rocksteady — Derrick Morgan "Tougher than Tough" 1967 bass line is mo' syncopated, e-guitar, epiano guitar slides into chord.
celebrates Rude Boys.

Rastafarianism - 1930 Haile Selassie (blk) ruled Ethiopia - icon for Blk people worldwide. viewed as incarnation of christ Rel, Soc., Pol. movement

Reggae formed in 1968 mo' political b/c mo' Rasta guitar mo' percussive used with delay loops - slapback

6ENRE

Reggae — Toots & the Maytals "Do the Reggay" 1968 new e-organ, Rasta drums, vocables (no lexical meaning)

hemiola = 2 time signatures on top of e/o.

Reggae — The Abyssinians "Satta Massagana" Astree 1969 / re-rel in 1976 rel., soc., + Rasta themes

meant to translate as: "Give him thanks and praise" to Haile Selassie

Reggae — The Wailers (Bob Marley) "Stir it up" 1973 love song, toured in UK live performance rhythmic g-stop

Reggae — Althea & Donna "Up Town top-Ranking" 1978 females work extra hard to break ceiling. "Strictly roots" - chain w/ competition

Sound Systems owned by liquor store. cultural meeting place. 1/3 largest in Kingston by 1978 Riddim — Jamaican slang. ostinato, instrumental track, rhythms ex: "Stalag 17" song based off movie

Version/dub = b-side of 45 that is instrumental Deejay on mic selecta chooses records.

Studio makes songs, producers had $ for idea/composer Singers from talent shows musicians from alpha school

some royalties, but lax $ law

Reggae — Dave & Ansell Collins "Stalag 17" 1973 instrumental organ track, slides into chords mo' like riddim, sax pulses upbeat

Dancehall — Sister Nancy "Bam Bam" 1982 dubbed over Stalag 17 w/remix. lotsa effects, she sings over.

Dancehall — Tenor Saw "Ring the Alarm" 1985 dubbed over Stalag 17 w/remix mo' bass & drum heavy singing mo' like live D.J. performance.

Dancehall — General Echo w/ Sister Bloss "Flowtee" 80's kings of slackness: sexual themes over Stalag 17

Dancehall — Bounty Killer "Gun down" 1995 version of Stalag 17

Dancehall — Wayne (singer) Smith "Under me Sleng Teng" 1985 Prince Jammy (Prod) all on Casio keyboard. Sleng-teng became own riddim also term for a drunk

Black Atlantic - African culture streams w/ Euro streams mixing from middle passageera.

Politics & Protest + Appropriation

Identity politics — doesn't belong in country but does grow transnational — cross-over btw countries: not focused on borders

Polyrhythms — multiple rhythms 2 against 3

music part of everyday chores. multi participatory enculturation — transmission of culture thru environment Rhythmically complex

Shona = (Zimbabwe) speak Bantu 800–1800 C.E. 1898 called S. Rhodesia 1923 became Brit. colony 1964 became free from Brit.

1980 = war on liberation born

music based on bring spirits to earth, possession trance to connect w/ ancestors. mbira = thumb piano vocals = head voice hosho = rattles

mbira buzzes from bottle caps ~~rusty~~ nailed in. e/ hand has polyrhythms repeating ostinato w/ arpegio's tuned to voice.

Chuning (indigenized w/ multi meaning) tuning + timbre. Rybato — borrowed time

M shona — "Nhemamusasa" (cutting branches for shelter during war for protection) mbira, hosho, no vocal 12/8 time

Kushaura (main part) Kutsinhira (interweaves 2nd part) 3 feel 1234 1234 1234 / 4 feel 123 123 123 123

Chimurenga Music = literally means struggle. for independence pop. form of music Rhodesia colonists took over broke for Uk.

Thomas Mapfumo (b. 1945) grandfather of chimurenga music initially pro Mugabe (dictator of Zimbabwe) Protest/liberation music start 1970's

shona music + western "rock" play guitar like mbira. he used to play heavy metal + rock created genre

Sent secret messages in songs tune in radio Contrafactum = established melody/rhythm w/ replaced lyrics

Used mbira to ask ancestors about the liberation war (1960–1980) comrade chimb

M chimurenga — "Nyarai" (Be Ashamed) (1979) pro-Mugabe after liberation, he shames people who didn't support liberation.

Afro-Beat = (Nigeria, Yoruba) Cuban ~~Jazz~~ + funk Yoruba = possession trance rituals. 15 min songs — no good for radio

mainly pol. Fela imagined Nigerian govt.

Nigeria : Yoruba, Hausa, Igbo fathers • part of slave trade • 1914 Brit. colony. 1960 independence lots of unrest after

Fela Anikulapo Kuti (1938–1997) started Afro-beat w/ Tony Williams (drummer) no like Islam/Christianity heavy influences

Saw indigenous cultures as lost • Wants a return to Afrika

Studied Jazz in London. inus at '69 rediscovered Africa (consciousness) BLK pwr. liked Malcom X autobio. - he wanted to not BLK leader. listened to funk + soul

Father = protestant minister/principal Mother = militant Marxist met Mau Mau "music is a weapon" listened to James Brown

M Afro Beat — "Let's Start" Fela trap drums + trumpet + guitar funk m.

Draw on Africa as imagination + aesthetics

African/American Funk = James Brown Add music by 60's R&B all band play like drum screeches (vocables) call & response w/ guitar horns ostinato's

M funk — "Say it loud, I'm Black & Proud" — '68 James Brown polyrhythms interlock on overlay sum of instruments.

Fela married 27 wives to protest marriage from colonists - sees musical duty to be Pol. musician. same for Brits in the here & now

M afrobeat — "Suffering + Smiling" ~ Fela hati '70's vocables "amen" "Allahuakbar" (god is great) christians + muslims suffer on earth for heaven.

reclaim Afro-Pol. upset that christianity & Islam ctrl Africa + Africans are mindless followers.

"music is weapon of the future" his sons Seun & Femi cont. music — inspired hiphop

"Pygmy" (Demography) Rainforest central Africa

"Pigmies" Greek mythology for smal. dwarfs means "other" for west stuck in primitive past

Forrest people/ Bayaka — trad. hunters + gatherers

disempowered — circulation of sounds further disempowers them

Unempowered — (no pwr in place in tribe) in Pol./ determination, SES, Rel

In appropriation media is dif. to ctrl. (academics + commercial)

Schizophonic Mimesis — split sounds to imitate (mime) schizo - to split phonic - sound mimesis - imitation

take sound from context to re-represent something even if intentional or not.

M pygmys — hindewhu — 2 reed flutes

M original source sibilation — "Watermelon man" 1973 Herbie Handcock he uses hindewhu he despises copying it b/c he's black

It further disempowers them b/c pygmies can't defend their rights.

Akuna — Choise, neg, soc. disunction) lack of noise kills the forest (silent) like sick

Ekimi — (noise, pos, soc. harmonious) Quiet but not silent some noise helps the forrest

Hippies to Hip-Hop

Ca history — 70 dif. indian groups ex: Chumash — Europeans came in 1500's — spa. missions started in 1600s

1821 mex. independent from spa. — 1830's revolts against mex. — 1836 Ca republic annexed in 1947, actual State by 1950

Nature Boys — subculture groups utopian vision — started in '40's — proto-hippies caught on in '60s

eden ahbez — (George Alexander Aberle) (1908–1995) — Jew orphan 1941 walked there to LA

lived under "L" of hollywood — played piano @ Eutopheon (healthfood restaurant) — German owned store w/ eastern healing medicines

inspired by Bin Pester — he did yoga very new — he inspired Beach Boys

drawn to eastern practices:
- Lebensreform — life reform, vegetarian, shirtless, grew hair, sleep outdoors
- Wandervogel — not being tied down to house, wandering

He brought

many Ger. came to Ca to escape draft in 1900. — S-con as promised land utopia

M. "Nature Boy" — hugely popular written in '40's (eden ahbez) — published in 1947. — autobiographical — recorded by Nat King Cole (1948)

eden asked beverage to give song on paper to Cole (he dressed like a bum) — Cole read it & loved it. agreed to meet on radio show.

eden showcased theme of nature and love. (eastern spirituality/hygiene); self-reflection, inward reflection, spiritual over material

"Greatest thing you'll ever learn to love is to love and be loved in return." — anti war - peace — was in movie "Boy with Green Hair" anti war movie

Utopia — imagined place of perfection — Dystopia — opposite state of decline/disaster

Ca in late 50's & early 60's • post WWII • Mass migration to Ca = mo' middle class = inc. leisure even for teens affected material culture/music

pop music for young people 1958 considered death of R&R (army drafts artists died) — Dick Dale altered surf & soul, & early psychedelic rock emerge.

Ca in Late '60s • '65 assassination of Malcolm X, Watt riots, 'Nam, '68 MLK assassination • neg side of drugs • musical experimentation • urban, dark settings • pessimism & paranoia

Love band • psychedelic rock — Arthur Lee (1945–2006) wrote about summer loving '67. — band had blk members — multi-racial to rep urban environments

Album: forever changes

M — "Alone Again Or" — Love — 1967 — about loneliness, mariachi elements, folksy, urban, minorish.

M — "The Red Telephone" — Love — 1967 — influences from 'Nam war & urban darkness & paranoia — like Syd Barrett stuff vocals dissonance — talked about 'Nam protesters worried about prison

Wild Wild West Hip-Hop

P. funk = parliament Funk (detroit)

Gansta Rap — (popular in 90's) Gonre name from at/sideculture based on what they talked about — artists pretered G-funk

Ca from 70's to 90's: urban blight — Ghetto is partitioned, decay of infrastructure — from Reagan's "trickle down" economics hurt lowerclasses

"What's up G?" G=means hip hop language refers to "God" - divinity of Blk man on east coast, west coast Add is to gangsta

Stagger Lee Caricature 19th C. of Blk man persists. ex: Ice cube & TuPac w/guns = also imparing image (Islamic)

M — "California Love" 2Pac ft. Dr. Dre 1995 intro has mad max tirednne apocalapse nightmare (dystopian theme from racetists) from party scenes

Drop: "wild wild west" as line marking locations of Compton" "west coast" place is important. tension btw (gang life & Ghetto living)

Ice cube holds mic. like gun to show "lyrical gun" - (like) Fela Kuti for music as a weapon.

M — "West Coast Poetics" 1981 funk Ronnie Hudson inspired Ca. Love song

M — "G in the Morning" - Iced Tea 1980's Stripped down drums, not overly produced, (anti police/laws) talk of police break down doors.

White flee - middle class & upper class move from urban to suburbs. (of) treated separation & allowed for decayed (ghetto) infrastructure.

Love theme for Ca. music. with tensions of Utopia & paranoia (come from 60's shift to dystopia)

anti authoritarian themes protest — (ex. anti draft) lyrical gun Gangsta Rap used caricatures as imparing images (still a paradox) (tension thing)

transformative/transitionary themes: Ice Cube wrote comedy movies. - some seen as trailers b/c of it.

M — "Straight Outta Compton" - 1988 N.W.A. - feeling oppressed by police (routine gang sweeps). express figurative violence (Cathartic experience)

had extreme exageration of tension. - hype street cred.

CB4 (comedy movie) made fun of this exageration of declining period. w/ Gansta rapper cameo's.

"Thriving Armegeddon not transcending it" - Racist implies violent caricature (connotations to) the desire to transcend. - miss intricate lyrics & images

Ice Cube video made post at N.W.A.

M — "5 mil. ways to kill a CEO" Cap bay area lyrics talk of lifes tough/unfair in ghetto

how enfranchized people take advantage of po' ghetto folk. - wants cities to rebel.

Lila framed by Hadra (Dinn) drums + Ghaita → Sat Guinbri section

Seated around team lead singer w/ Guinbri and vocal backups responses - ch singing (incense burning)
5/4 time distinctive to Hamadsha use common refrains: God is eternal, no god but God.
many Sufi: exclude non muslims

healing ritual generates Baraka, appeases Djinn. ask god for help, Some come for social aspects (women are present)

Trance - way to deal w/ possession "extraordinary psychic state" many people pass out. - helpers catch them
Psychologially + physiological exhausted @ end. - end w/ big feast Cathartic experience

Therapy - restoration of "old self" renewal + reinvigoration

end Lila w/ hadra rhythm it speeds up to release aisha (djinn) shut off lights to release her
then eat a big meal & sleep.

Global Hip Hop

Ceza - Turkish MC (2004) sound of Istanbul (born) connects/disconnects w/ U.S. hip hop roots - posters on wall = crew < hip hop heroes: U.S. civil rights leaders

• Adopted sounds + material culture from media. • differentiates his music to be politically serious/ • encourage breakdancing instead of drugs. • Sampled the Baglama Saz • Language (inserted the music)

Cosmopolitan hip hop connects cities w/ c/o ex: Istanbul to Bronx/LA

Ian Condry: "Global sparks create local fires"

Arjun Appadurai: flows & scapetypes ex: Japan accepts huge west. culture, but the immigration is strict

Origins of Hip Hop (make something out of nothing)

MC, DJ, B-boying (breakdancing), Graffiti

-70's in S. Bronx discovered in 1979. in Urban blight/ghetto - decayed, displaced people often near highways

Communal block parties. - splice electrical cord for amps

"From Afro Americans, to Caribbeans, Hip hop is a culture to help navigate marginalization" — Tricia Rose

Global phenomenon from start 1st graffiti artist was Brk.

1st DJ Kool-Herc (from Jamaica) leading father of hip hop. → carried huge speakers in car convertable backseat.

(b. 1955) Kingston Jamaica in Sound system culture moved to NYC @ 12 introduced "toasting" — Rap precursor (big rapping) and "The break" - sampling drum breaks used 2 turntables to keep playing break up/same record

2nd Afrika Bambaataa — (stage name of a perceived African heritage) (b. 1957) S. Bronx, but parents Barbados, organized Zulu Nation for imaginary connections to S. African Tribe seen as positive alt. for gang life

M ← "Planet Rock" 1982 Afrika Bambaataa Jackets-out Native indian headress lots of jiggling dancing & breakdancing "Rock Steady crew" - Professional breakdancing team.

he sampled lots of sounds from white ger. Group: Kraftwerk — Funky Gers.

Islamic Soundscapes morocco

Soundscapes - (ex: "Hand scapes" tied to visuals) Western culture values visuals over other senses. - Ambient noise tells environment - hearing v. listening. - Condition people, shape/reflect identity, organize time & space - Intent of sounds ex: using Adhans to tell time + organize schedule regardless if attend or not. - Engrained in community.

Niya = (intent/intention) is important for music.

The Shia - want direct bloodline from Muhammad to rule. The Sunni - want mo' merit for rulers.

Islam - prophet Muhammad (570-632 BCE) recieved revelation of Qur'an. When pray in cave The angel commanded him to "recite". - emphasizes aural culture

musical, but not music.

Recitation of Qur'an - is a daily activity to show intention/piety/faith for both professionals & non-professionals. (Spoken outloud) prof. use ornaments on vocal solo - Abdulbasit Abdulsamad (donuts) recited it @ work
melismatic quality no instruments melisma - mult. notes per syllable/speak Quranic arabic which is higher form of sophistication = beauty + divinity

Baraka - blessing/healing from God/saint to provide spiritual energy. Open palms gesture to recieve blessings.

Morocco = "Al-Maghrib" (place where sun sets) furthest western islamic area. monarchy/parliament King Muhammad VI as Pol. + Rel. leader heredity since 1700 - decendant from Muhammad.

Uneasy juxtaposition - appropriateness of music. adhan has musical qualities but its not music. music as state of mind. so separate it w/ God

2 MP3's - Adhan - (can be musical or lawful (w/o music)) - call to prayer, long pauses w/ lots of ornaments. to allow responces - seenas Rep for Gods beauty (muezzin whisper) Lawful Adhan - wells, slides in incipitch seenas more godly b/c no musical distraction

structure (1) "God is great" repeated intensity that no other god but God
(2) "Muhamed is messenger for God"
(3) "Come to pray" "come for success/salvation"
(4) "God is great"

e/ 2 repetition has ornaments & melisma, 1st phrase goes to 5th, & last phrase goes to tonic. = cadense

Oud - (wood) or al'ud or ud around since 800 BCE originally had skin head but replaced w/ wood top.

Maqam (s) - scale Taqasim = improv. melody in maqam w/ pauses btw phrases,

Big debate for having a centralized Adhan, to get rid of overlapping sounds - against tradition. businesses near Mosques no like 3am Adhans.

Music arabic is musiqa in bazar mornings shops blast Qur'anic recitation & in afternoon they blast pop music - all types

Video - Tala' al-Badru 'Alayna - (The full White moon has Risen Among Us) Muhammad's 622 Journey from Mecca to Medina. ← praises him taught @ an early age

Open palms gesture. trains kids about Rel. + culture

Madih - (arabic poetry) poetry to praise (usually muhammad)

Praise is dif. than worship. no worship the prophet.

poetry was written in elevated state, so it allows listeners to get a glimpse of original writers state of being.

Video — Ramadan - holy month for fasting (try to be pious) from sunrise to sunset but @night there is a feast. celebration @ someone's house - private

4 singers, w/ short violin breaks - played on knee, heavy drum pattern. Sing Generic refrain "there is no god but God" same as adhan, had hadra movements (breathing +)

Darbuka - goblet shaped drum Tar - tamburine-like drum

Sufis use sand as path to God. Suf = wool - wool seen as poor man's cloths Tasawwuf - practice Islamic mysticism

- against upper 1% wealthy greed. - Sufism react against rich kings/leaders inspired by Muhammad who is seen as a giver.

- organized into orders/branches led by Sheik (old man) w/ lineage to prophet to add Baraka + Charisma

Marginalized in Morocco in 20th c. during independence, but now is promoted by Govt. shift from Anti-sufi to pro-sufi

"Oldest Ally to U.S." From Am. Revolution. Morocco promotes sufi bc mo' peacefully b/c 9/11 attack and 2003 Moroccan Al Khaida attack

Sufi's seen as less radical by west. Sufi attend same mosques as muslims. Islam has no clergy b/c in Qur'an everybody is equal. no heirarchy. But sufism there is no hierarchy

Sufi-mosques have cremated remains of sufi leaders = tomb very controversial to do Rel. gathering in mosque tomb

dhikr — (to remember) mention his name to mention God (important for all muslims) Samā' - (listening) as spiritual process hearing bring one closer to God in Sufi today semi-private event

semi private. could be weekly Samā' - once a wk. or for special occasion. ritual + stage contents

Poetic themes - (love for devine) or (Intoxication w/ devine) Rep thru wine all else but God exists. (promoted by Moroccan Sufi nationalism)

① Seated - relaxed persian, listen to poetry, slow ease into participation venerate saints, w/ prophet + God ② Hadra (presence) Swaying, heavy breathing, standing Intoxicated w/ God

needs lots of training/indoctrination to understand it

Video — Samā' celebration for Mawlid (birth of prophet) annual celebration Ibn Farid Medih poetry

drank hot green tea w/ water. in hadra standing + swaying + breathing wine ode poetry songs - improvized solo occurs

imagery of drunkenness or lust as metaphor for intoxication love for devine God. requires training to reach that State

Words & music written from heart from heightened experiences/consciousness allows listener to experience same state

only sufis al-Fanā' (annihilation) of ego/individual so only God exists you no exist.

General muslims Tawhīd (oneness with God) nothing exists but God, or everything is God.

Djinn - in Quran (spirits) come from smoke many muslims see them as superstition. not Sufi's

Sufi order Sidi 'Ali Ben Hamdush (1720-1784) "popular" sufism lowerclass Hamadsha Lila - all night healing ceremony 9pm-6am duration

- would also go to Doctor.

beginning Lila, outside house candles, white robes Hadra swaying = entranced reflect inner Djinn. some have blood ritual sections.

all night multi part organized tonal = instrument & vocals

Ghuwwal - big drum on shoulder Tarija - sml. drum off in hand

Ghaita - dubbereed oboe/flute Guinbri - lute

Brazil Nationalism Race + class

Samba = 1st Brazilian music similar to Jazz, around 1900 started Afro roots from slave trade.

Song contest for Carnival. @ first seen as too Afro + too primitive. morros - people of Afro Favelas - slums in hills (live morros)

blend of Afro, Euro, & indigenous music. From Bahia (Salvador) → Rio de Janiero Candomblé (voodo + catholicism) trance rituals

Carnival ← (fused / basically a Mardi Gras) annual celebration (cursing) before lent. (fat tuesday) to ecstar

Nationalism = a nation identifies/defines to itself & others aural learning rep. of nation. pride in identity w/ similar values

- culture + music appropriated - race + class issues

Brazil History: portuguese colonized in 1500; imported slaves became part of kingdom in 1808 after king hid there b/c Napoleon

• 1822 empire of Bra, • 1888 abolish slavery • 1889 became a republic

Slavery | N. Am. | "family oriented" | Protestant, no allow drum/dancing | S. Am | mo' satelite | Catholics allow retain mo' Afro cultures |

• Vargas 1930-'45 dictatorship, 1960's military uprising, 1985 civilian rule 2011-16 woman president, but was overthrown

Mystery of Samba — repression of morros/favelas. Some radio/carnival spread it passed approvals to rep. Brazil (part of Nat. identity)

- radio spread music 1920s - whites marginalized "popular classes" (the Afro creations) (masses) mo' middle class (white) dominate airwaves

- Afro people no on radio - so (Afro) they made their own samba schools in favelas 1928 started. prepare for Carnival trad.

asfalto (white middle class (asphalt roads)) v. morro (favelas - hills dirt roads).

Noel Rosa - 1930's, early Samba icon (white asphalto) friends w/ Cartola (Cartola didn't get credit/popular till 70's revival)

After WW II Nationalism mo' optimistic redefine Bra. to be slicker (troopers era) 50's thru 60's — Bossa Nova start.

Bossa Nova represents new art music, sophisticated, modern (against Carmen Miranda caricature) smoother-out soft voices, mo' harmonic but inadvertently eclipsed samba leaves out (marginalizes them) Afro people

Saudade - portuguese (bitter sweet longing) (good to feel pain)

• Afro artists marginalized by samba + Bossa Nova in country and in musical representation of the country.

1960s Bra. Tropicalia = rock w/ Bra elements (cultural cannibalism) heavy in gender/sex themes (cross dressing) recognized Afro-best & indigenous cultures

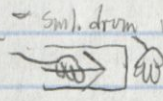
Optimism faded 1964 military coup/ anti-artistic regime (mo' protests) mo' political

67-69 broken up by govt

instruments

Cavaquinho - (looks like Ukelele)

Cuica - sml. drum w/ stick inside rubed w/ wet rag



Pandeiro - (tamburine drum) hand drum w/ rattles on rim

Surdo - bass drum worn @ waist (samba reggae) bateria samba percussions for marches

Samba — "Pelo Telefone" (1917) Bahiano & Donga (carnival) won samba song competition. new tech to talk w/ family
builds nationalism. lyrics legitimize samba b/c cops no breakup band. - played on Radio & Paris's
7-string guitar w/ lots of bass runs melody. Sax/clarinet. backup singing

Samba — "Malandro Medroso" (cool/trickster) Noel Rosa 1931's (Lyrics) street hustler image. guitar bass line runs his cavaquinho - swing

Samba — "Sim" (yes) Cartola 1975 love song + comentary on his late recognition (from friends, friend of Noel Rosa) (bittersweet) guitar, no dissonance
cuica back, cavaquinho, pandeiro, clave, surdo-like drum

Samba — "Chica chica Boom Chic" Carmen Miranda 1950's Brazilian hollywood caricature of samba. (agricultural emphasis (fruit hats + such)
Bra. is ashamed of portrayal. spurred Bossa Nova.

1st Bossa Nova — "Chega de Saudade" João Gilberto 1968 composed by Antonio "Tom" Jobim (both were ateists) (redefine Bra. music)
(nomo'saudade nomo'longing)
trap kit, flute, guitar w/o bass runs
Soft intimate singing. Smooth ethereal, orchestrated. → Samba rhythm in Rt. hand on guitar. Bra upset it became Existfening
1960's Bra. redefining two military dictatorship - they want to move forward to become industrialized. (seen as sophisticated life
crooners in U.S.

Bossa Nova — "Undiu" João Gilberto 1973 apex of genre. no lyrics only vocable. guitar, vocable, (brushes) percussion on phone book
- mó abstract

Bossa Nova — "Aguas de Marco" Antonio Carlos Jobim (Tom) & Elis Regina 1974 duet call & response, harmonizing,
(piano)
whistling, my playful (abstract lyrics read list) revival of spring. Counterpoint w/ acc. bassline. abstract poem - musically complex piece
Jobim + Gilbert celebrated by Bra. (some see it as white-washed samba)

Tropicalica — "Tropicália" Caetano Veloso 1967 Experimental style w/ samba rhythm w/ big band Jazz sound
by Caetano + Gilberto Jr arrested b/c cross dressed.

Ethics

3 Types

① Descriptive ethics — describe/categorize diff views

② Normative ethics — categorize if morally right/wrong, goodness/badness

ex: It is morally right for S to do A if and only if ___.

___ is intrinsically good/bad if and only if ___.

___ is a morally good action if and only if ___.

③ Meta Ethics — do moral claims have truth values to it? is it reasonable?

Conventionalism

It is morally right for S to do A iff S's doing Action is approved by the vast maj. of people in S's society

= foster tolerance ≠ only side w/ maj. of people - Herodotus (Egypt)

Majority of society decide which morals are right. ex: Own slaves in TX in 1840's (Nazi Objection)

Conv. has no moral progress/decline only Δ. ex Ger. in 1890 (accepts Jews) V. 1936 (persecute Jews) Δ in morals

Moral Relativism - 3 types can only pick 2 @ max (contradictions)

① descriptive relativism - see above, ② Conventionalism - see above, ③ meta-ethical relativism - no moral truths = no moral opinion above the rest

"What is begging the question" = circular logic w/ conclusion as one of the inputs.

③ ex: The argument from disagreement

① widespread & persistent disagreements on morality ② If there are ① on M then there are no M facts ③ ∴ there are no moral facts

-premis 2 is false b/c lots of widespread agreement on a subject.

Goldbach's Conjecture: every even # > 2 is the sum of 2 primes.

we have no proof yet, but it's true so we must believe it w/o prof

Socrates (469-399 B.C.)
↓ pupils
Plato (428-348 B.C.)
↓
Aristotle (384-322 B.C.)
↓
Alexander the Grt (356-323 B.C.)

Where Aristotle books were read = maj. civilizations followed

Theoretical sciences = seek knowledge for own sake ex: Astronomy

Practical sciences = seek knowledge to do something ex: engineer bridge

→ ethics top dog (micro)

→ Political science top dog. (macro)

Both about concern for good of man

man's function = Eudaimonia = to live well; happyness thru actions; flourishing

+ Greatest Good attainable

2 caveats of ethics + politics : ① Precision (be precise enough as subject allows)

② who to study it? – not the young b/c not enough like xp. – nor immature b/c they no use reason

What supports happyness as the Grtest Good?

– common opinion – opinion of wise – meets criteria of finality & self-sufficiency

Sometimes we desire X for the sake of Y, Sometimes we desire a thing for its own sake.

If X is desirable for its own sake and not for the sake of anything else, then X is a final good

* "A good is self-sufficient when its pleasure in a life makes that life desirable and worthy of choice and lacking in nothing" — Aristotle (on happyness (eudaimonia

psyche is word for soul (soul is form of living substance) Substance — matter / form Combo ex: snow ball, snow, ball form

Rational soul	Calculated reason – dynamic context truths Theoretical reason – static, eternal truths	] intelectual virtues help acquire btw True/False
Appetitive soul	– sense perception – desires – locomotion	] moral virtues help use emotions rightly
Vegetative soul	reproduction assimilation of food	

man's ergon is an activity of the soul in accord w/ reason. – flavish

"a good _____ flavishes if it performs its function well" ergon = function

* "Eudaimonia is an activity of the soul in accord w/ virtue & if they're several in accord w/ the best & most complete and in a complete life."

— Aristotle

live & exercise moral virtues in a life. – to live well.

virtue = characteristic subset of ergon to help preform ergon

♫, pleasure, honor, virtue, contemplation – elements of happyness.

happyness possesses moral and intelectual virtues in life by exercise of reason to flavish

– right environment, & right form.

Virtues are acquired (well adjusted nam. human)

Teleological Theory of Nature

① every living substance & organ of a living substance has an ergon. ② Nature does nothing in vain

* "Man's function is an activity of the soul in accord w/ reason or not w/o it." (think, choose, + desire rationally)

posses + use intelectual + moral virtues make a life good + performs man's function well. live it well

Can what happens after one's death affect the happyness of one's life? — No, cannot Δ happiness of a dead's life

happyness can be lost by super disasterous event. but people w/ virtues more flexible/happy turn misfortune

happyness is not a mood, but an activity

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* "Moral virtue is a habit of the soul concerning choice and consists in observing the mean relative to ourselves, a mean such as a man of practical wisdom would observe."

every virtue btw 2 extremes

Habit is an acquired (not unthinking, but can be) disposition to act/feel a certain way. noone born w/ moral virtues only capacity to acquire it

Vice (excess)	Virtue (excellence of character)	Vice (deficiency)
Spend thrifts	Generosity (loves $ to right degree)	Stingyness
Self indulgent	self-control	insensitive

↕ vice more closely resembles virtue - err on that side of vice.

virtue leanings depend on circumstance (mean) ≠ acquired devo. to be clear to mean asymptotal

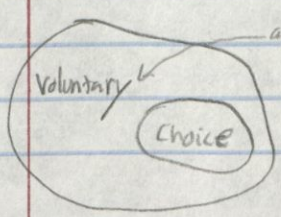
~ lots of people have a false perception of mean. ex: Coward validates fleeing in battle.

Aristotle characterizes virtuous acts
① Preform it knowingly
② for its own sake
③ from a firm and stable character

wish — to desire X

deliberation — rational investigation into means to bring about some ends

choice — deliberate desire for things w/in one's pwr.

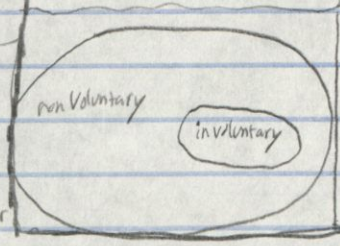


agent/cause of circumstances

(all choosing has deliberation)

Action as non-voluntary
① action is due to constraint
② action is due to ignorance of particular circumstances.

Involuntary action
① due to ignorance of particular circumstances
② Brings sorrow + regret in train (when one acts under mistaken meanings)



Voluntary
an act is voluntary when agent is the cause of the action & act with knowledge of particular circumstances

(ignorance of general moral principles are not excusable)

megalopsyche – greatness of soul (crown of virtues) high-minded man, has done great things
m° virtuous than others + knows it. right amount of pride of what accomplished

Symptoms = slow gait, low voice, as much pleasure in knowing his virtue over others as finding someone with m° virtue than him
knows when to assert his greatness.

Virtues (5)

Rational Thought
- **Theoretical** – eternal unΔing truths
  - (5) **Sophia** (theoretical wisdom) – combo of 4+3 applications for higher means.
  - (4) **episteme** (science) – good @ drawing inference from 1st principles
  - (3) **nous** (intuitive understanding) – good @ grasping 1st principles ex A=B ∴ B=A
- **Calculative** – things appropriate for their Context
  - (2) **phronesis** (practical wisdom) – deliberate on means for ultimate end of life
  - (1) **Techne** (art) – produce good/act practically rational

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practical wisdom – has probability to suggest state but no certainty
Theoretical wisdom – gives certainty for eternal + unΔing objects (have knowledge of god.)

phronesis = make good decisions for oneself ≠ good understanding nor cleverness
can't have intellectual Virtues w/o moral virtues. (edit-ctrl) M.V. prevent corruption of practical thinking
M.V. (good choosers) requires Practical Wisdom (helps validate choosing)

Friendship Types

un equal friendships
teacher:student, husband:wife

1. **Utility** – lasts as long as utility lasts ex: sports teammembers
2. **pleasure** – " " ← (common for young)
3. **Virtue** – love/admire their character (longest lasting) m°/w/ other people

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pleasure can be both good & bad
P. from morally good activities = good P. from morally bad activities = bad

Plato
- **Righteous indignation** – pain @ seeing wicked prosper. (this type of pain is good)
- **spiteful behavior** – Joy @ other's pain (P. @ others pain = bad)
- **mixed pleasure** – pleasure preceded by pain ex: eat after hungry (illusionary neutral pleasure)
- **pure pleasure** – contemplating see how things relate ex: see Mat. beauty + appreciate them

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Aristotles Contemplative life = best
1. pure pleasure
2. leisurely
3. self-sufficient
4. life most God-like
   - has no body ∴ he must think

#2 life is based on M.V. + politician

Best life for X is X performing its ergon well.

Fallacy of contemplation – every part of man has a function ∴ man has a function
truth of parts ≠ truth of whole.
ability of eyes... ≠ combination of use.

Utilitarianism

in Eng. Bentham then Mill

Act U — no apply standard to maximize morally right act if it maximizes utility

Rule U — apply if act right to maximize utility if it fits a moral Code

Quantitative Hedonism — every state of pleasure is intrinsically good; every state of pain = intrinsically bad

intrinsic value of an episode of pleasure/pain is function of Quantity, duration, intensity

Sum of all pleasures (+)(hedons) and sum of all pain (-)(dolor)

Bentham

It is morally permissible for S to perform act A IFF their is no alt. to A for S that produces greater utility than A. Sperbonis

	Moe	Larry	Curley	total utility
	5	4	3	12
Act	6	2	2	10
	3	3	3	9

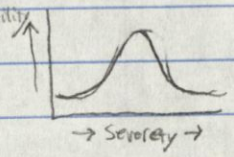
if C was all 4's then either A=C as the same
no worry about inequal dist.

mills

① why punish? Mill: Respond to soc. prob. when punishment maximizes utility.

② How much punishment? punish in amount to maximize utility.

③ who punish? punish whenever maximized utility to punish.



ex: highwayman in Fra. robs trilled b/c death penalty for both — appropriate punishments — but Chin highwayman only robbed b/c death penalty for murder only not robbing

ex: Chin Lights against yath hooliganism by publically killing a few to set example.

Objections

Lack of Time obj

X ① must always calc. Ult. before act. ② not always right ∴③ Act. Ult. = False

Bentham: ; if calc. ult. no maximize action then no calc. normal humans know "rules of thumb" to do right thing. "no need to reinvent the wheel"

Too High for Humanity obj

X ① act is right only if motivated by desire to max ult for all mankind. ② not always right. ∴③ Act Ult. = False

Mills: relate actions by right/wrong (no relation limiting) or by praiseworthy/Blameworthy (type of motives) (good/bad consequences) (can have combo)

goodmotive — duty, benevolence, charity

badmotive — greed, spite, malice, selfishness

Doctrine of swine obj

X ① spend all $ on most pleasures ② not true ∴③ act Ult. = False

Bentham: counts Quantity of pleasures but could have diff intrinsic values

Mills: counts Quantity & Quality of pleasures in

intellectual pleasures > physical pleasures | mills: competent judge

test to make people aware of higher pleasures" those aware of them will choose them instead. intellectual pleasures engage you more. Its why Socrates wanted public edu. to help masses desire higher pleasures.

Promise to the Dead man

① better to promise to maximize ult.

② but is not

∴③ act Ult. = False

Shows that there is no important things than utility for theory

(Ult. is from intrinsic value of consequences of actions)

Think Dreyfuss case in Pra

Punishing the Innocent Obj.	Morality of Punishment Obj.	ex: Juror decides what max. ult. in observation
① morally right to punish innocent man in act ult.	① only thing that matters to rightness of punishment to max. Utility	
better to cut ones losses. — X ② but its not right	② but its not. (guilt matters)	
∴ ③ act ult. = False	∴ ③ act ult = false	

Ideal moral code based on humans condition + standard of living. ex eskimo's can't take care of the too old/crippled. b/c too much burden

Rule Ult.

Current Utility of moral code: C for a society S is the net ult. per person that would be produced if C current in S.

ex: compromise of playing loud music in a flat to certain hrs.

Its morally right for S to do act A Iff S's doing A is permitted by the ideal moral code for S's society

(is correct if vast maj. accept + know others accept it too)

Conventionalism act = right if permitted by current moral code. Rule Ult. act = right for ideal moral code, not current code.

Loopholes

Promise to Bad Man — by keeping promise w/ escape clause to null current code.

Punish the innocent — (act in moral ideal code)

Feldman: Marriage Obj. = ① IMC = no monogamy ② no abide by IMC ∴ ③ wrong to practice it.

Lemos OBJ. = our moral obligations made from reality not an ideal moral code

ex: monogamous because of interpersonal promises to e/o.

Personal Compliance (game theory) only save live by ideal moral code others don't. Rule. Ult. lacks scale of context.

Immanuel Kant (1724-1804)

born w/ prussian simplicity

Virtues only good when conjoined to moral goodness. moral goodness used to obtain eudaimonia

A person's morality

Incentive for duty is not enough to make it morally good

① Act from duty

② Act from self-interest ex: put $ in retirement

③ Act from immediate inclination ex: hankering for something

they conflict w/ e/o

Only actions done from duty are morally good

Reason → Will (or) Desire → Will

act out of reason is duty

act out of desire is desire

Kant believes that desires + emotions are irrelevant to morally good. ie: duty over pwrs desires

moral Law has authority over you regardless of personal desires.

"Act only on those Maxims which you can consistently will as a universal law [of nature]." = Categorical Imperitive (commands)

Unconditional — Categorical Imperitive — Do B! , obligatory

Conditional — Assertoric " — since you want A, then do B. , a desire that can't be given up

Hypothetical " — if you want A, then (ought) do B. , a desire that can be given up

Maxims = actions based on principles. "Whenever I am in condition C, then I will do A".

(duties)	perfect	Imperfect
self	• no kill oneself from self love	• to develop talents
Others	• no make false promises	• help others in need

Consistent Willing

① To will A where A is impossible

② to will A & B where A & B are impossible

if violate a perfect duty: guilty of #①

if violate an imperfect duty: guilty of #②

perfect duties — must perform everytime occasion occurs.

Imperfect duties — some latitude of context for performance.

Cat. Imp. = It is morally permissible for S to do A iff S can consistently will the maxim of A as a universal law

P.M. Whenever life offers me more pain than pleasure, I will kill myself from self-love

not a universal maxim as a law. X U.M. " " " " they "

why can a thing have two functions

Kant says: function of self-love is to preserve life; then self-love would have opposite functions in U.L. ie: impossible

P.M. whenever I am comfortable I will let my talents rust

not a U.L. X U.M. " " they "

willing inconsistently entities

Kant says: rational beings wills talents to develop

not S. Sea Islanders

P.M. Whenever I need $ & can get some by making a promise I can't keep, I will make the promise

U.M. " " they "

- no one would be willing to accept/offer promises

Can't consistantly will everybody do do moral maxims even if they are true to individual

Cat. Imp. is a poor test on whether actions are permissible

Miss Perkin's Test

P.M. no true/false writing term papers, So buy one & say it's mine / no one would assign term papers.

V.M. " for everybody "

Person as a Mere Means

"It is morally right for S to do A iff S's doing A treats no human being as a mere means"

barber to haircut

treating someone as an end in himself/ & treating someone as mere means ex: slavery, rape.

X A treats B in a way that B objects to. — but prisoner can object to going to perish (not two Ted Bundy

assume B is rational

X " & A's treatment of B is not a consequence of B's actions — burglar w/ open door case

X "It is morally wrong for A to do X iff A's doing X would be prohibited by a rational moral code for A's society."

ex: 1/2 society = rich other 1/2 = poor; rich no want to share = selfish; poor want $ from others = selfish

Lots of problems w/ theory, lots of unclear sections. It doesn't explain duties to animals and duties to humans.

Says there is no right answer ↘

Ross's Theory

Is it Morally right for S to do A iff ____?

Prima Facie duties — morally significant reasons to do Acts. lists 7 but could be mo'. believed to be Moral Objective Facts

Backward Looking duties (Rooted/look @ past)
- Promise-Keeping
- Reparations
- Gratitude — benefits to you & others
- Justice — good/evil merits

Forward Looking duties (possible actions in future)
- Non-Maleficence — prevention of bad state of affairs
- Beneficence — promote intrinsically good things: intelligence, acts of M.V., types of pleasures
- Self-Improvement — make ourselves mo' virtuous.

|ABS| duty or our duty all things Considered to perform weightiest prima facie duty.

In measuring |ABS| duty Ross uses Intuitivism — no formula, but only Judgement from perception

Aristotle's NOUS = (i) no formula to decide weightiest P.F.D. is.
(ii) we have basic non-inferential knowledge that certain types of actions are P.F.D.

Ross's views are a non-theory that don't describe right + wrongs in specific sceneries or in formulas.
Ross responds by focusing on M. theories that are true for a variety of salient issues.

Are there any Moral truths?

Cognitivism
some M. Judgements have a truth value &
some moral Judgements are known.

- **Naturalism** (moral prop. only detected by natural prop.)
  ex: detected thru senses, scimethod, knowing, introspection.
- **non-naturalism** (moral prop. not detected by senses, scimethods, introspection)
  ex: prop. that all options are possible.

non-Cognitivism (no moral Facts)
no moral judgements have a truth value &
no moral Judgements are known.

- **Emotivism** (moral Judgements describe emotions)
  ex: murder is wrong = murder! Boo!
  mercy is good = mercy! Yes!
  (explicatives of attitude)
- **Prescriptivism** (M.J. = disguised commands)
  ex: murder is wrong = don't murder
  mercy is good = show mercy
  (commands)

Logical Positivism — only statements w/ a truth value can be tested empirically by senses or science. ex: (can't test) moral for Oswald to kill Kennedy.
Just b/c it can't be tested on truth value doesn't make it untrue.

3 arguments for Non-cognitivism

① Argument from Disagreement

X ① if persistant & widespread disagreements about subject M, then there are no facts on subject M

② There are widespread & persistant disagreements about ethical matters

∴ ③ There are no facts about ethical matters.

ex: dino's extinction has contrasting facts, but one common fact/side

② Argument from Motivation (M.J ≠ facts, but are emotions or commands)

X ① No factual claim is intrinsically motivating.

X ② Moral claims are intrinsically motivating

∴ ③ Moral claims are not factual claims

① Rejection: ① ≠ true rational beings make moral claims intrinsically motivating either by not agreeing with it or agreeing with it, either option has care into it.

② Rejection: ② ≠ true moral claims only motivating if we care for them, says everybody cares for them, but what about psychopaths? - they no care.

③ Argument from Explanation (ex chicken no lay eggs. So witch must've cursed it. but there is a better explanation)

X ① Facts of kind K only if facts of kind K sometimes explain what we observe w/ our senses

X ② Moral facts never explain what we observe w/ our senses

∴ ③ there are no moral facts

① Rejection: ① ≠ true Some facts don't explain what we observe w/ our senses (Goldbach's conjecture) ∴ some facts don't explain from our senses.

② Rejection: ② ≠ true (Moral facts explain things) ex: Rev. in S. Am. b/c of injustice in it as cause or Hitler's holocaust b/c he was evil

non-cog. think: system unjust to cause Rev. Hitler hated Jews b/c psycotic (emphasis on psychological facts not moral facts)

Deductively Valid Argument — impossible for premises to be true & the conclusion false.

Deductively Sound Argument — impossible for premise's to be true & conclusion false, and all premises are true (they are also valid C's but not vice versa.)

Metaethics:

① If non-cog. = true, then no moral arg. are sound (no one believes in them)
② Some moral arg. are sound
∴ ③ non-cog = false

① If non-cog. = true, then all moral are valid. (even if they are not related)
② Some moral arg. are not valid
∴ ② non-cog. ≠ false

① If non-cog. = true, all M.J. are expressions of Commands or emotions.
② Some M.J. are not expressions of commands or emotions
∴ ③ non-cog. ≠ true
ex: Wrong to murder JFK, then Wrong to murder w/ axe (no expressions or commands)

Dieter: (Nazi): "All Jews should be killed" "It is morally right to kill them all" (false claims)
① If non-cog. = true, then Dieter's claims are not false
② But they are false
∴ ② non-cog. ≠ true
in world of non-cog. he is neither true/false. - incompatible w/ Sand arg. † all M.J. = ≠ true

If naturalism = true, then all moral prop. = natural prop. ex: water = H_2O, temperature = mean energy of kinetic

rightness = ?

S's doing A is right iff S's doing A —

(can't be done)

Moral statements have truth values; some are known.

personal bias in that young people generally form Identity crisis stage.
- Eriksons socio-emotional

Imagine a totally useless contraption where the relation of the parts have function but the object itself has no function
ex: a brick wall with half a doorknob adhered to it. it twists, but no opens.

Rational thought that man has is like this, - unclear reason why we have it and other organisms don't.
↳ evolved out of survival. 'more clever = more' kids survive = passed smartness on. but reached a point when society started when
art is indicator of freetime + wealth to pursue useless pursuits city culture transcended survival.

by pondering and thinking about possible overall functions for a purposeless contraption humans exercize their ability of rational thinking.

for whatever justifications derived from this rational thinking on the possible function of a purposeless contraption is an overall exercize in choice.

the decision to think or not think, and how they think on the object (flexibility or not) is main function with regards to rational thinking.
it is the choice to exercize rational function on what, and how & how long.

∴ function of man is to choose what to use rational function on. & all the discussion of others
of rational functions + their exercize's purpose is to give it to the next generation for them to decide what to use it on in an overall effort to achieve eudaimonia.

ex: most see Dahlmer as a serial killer to be avoided + learn of how they exist/act
Other psychopaths might see him truly as a hero. the choice for either helps reinforce/shape your function

Function of man is to choose the appropriateness (ie: methods, subject, amount of time, & creation + context) in applying rational thought
for whatever you are interested in, and one's spectrum of appropriateness is possibly given to others (mostly the young)
for them to choose the ranges of acceptance, & nit-picking + rejection for their attempts to achieve eudaimonia for their interests.

all about using rational thought to attempt to furfill one's eudaimonia & for others to observe + decide how to use it. in their attempt to
achieve their eudaimonia. It's all about the choice of rational thought

aristotlean eudaimonia

A Good is Self-Sufficient when its pleasure in a life makes that life desireable and worthy of choice and Lacking in nothing

~~aristotlean moral virtues~~

Eudaimonia is an activity of the soul in accord with virtue and if they are several in accord with the best and most complete and in a complete life

aristotlean moral virtue

Moral V. is a habit of the soul concerning choice and consists in observing the mean relative to ourselves, a mean such as a man of practical wisdom would observe

Econ Micro

Sean Franco

Ch 5 Elasticity — measure of responsiveness (how much Q↕ for a Δ in P)

$\varepsilon_{D_{ors}} = \left| \frac{\%\Delta Q_d}{\%\Delta P} \right|$ (% decrease)

$\varepsilon_{D_{ors}} < 1$ = inelastic (steep slope, closer to vert.) $\varepsilon_{D_{ors}} = 1$ unit elastic $\varepsilon_{D_{ors}} > 1$ elastic (slope closer to horz.)

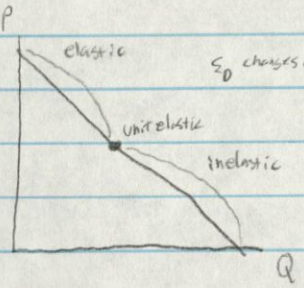
$\varepsilon_{D_{as}} = \left| \frac{\Delta Q}{\Delta P} \cdot \frac{P_{avg}}{Q_{avg}} \right|$

= inelastic (steeper slope)

= elastic (flatter slope)

ε_D of Demand

1. availability of substitutes (mo' substitutes = mo' elastic)
2. Necessities v. Luxuries — necessities: inelastic; Luxuries: elastic
3. Def. of Market — Narrow def. → mo' elastic; broad def. → mo' inelastic
4. Share of Income on Good — Larger share → mo' elastic
5. Time horizon (time elapsed) — mo' time = mo' elastic; mo' time to Δ behavior.



Total Revenue = P·Q

$\varepsilon_D > 1$ (elastic) TR direct down w/ Q; $\varepsilon_D = 1$ (unit elastic) TR = 0; $\varepsilon_D < 1$ (inelastic) TR direct up w/ price

Income ε_D same formula: $I\varepsilon_D > 1$ (income elastic) (normal good, Luxury); $0 < I\varepsilon_D < 1$ (income inelastic) (normal good, necessity); $I\varepsilon_D < 0$ (neg) (inferior good)

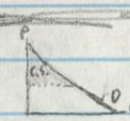
ε_D factors

1. Resource substitution possibilities — unique resources = less elastic; common resources = mo' elastic
2. Time Frame — mo' time = mo' elastic

Ch 7 Welfare & efficiency

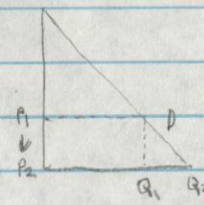
(MB − P) (willing to pay − have to pay)

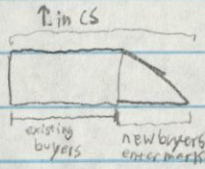
Consumer Surplus (CS) = amount a buyer produces minus amount pay to create it.



Area of Triangle = $\frac{1}{2}(b)(h)$

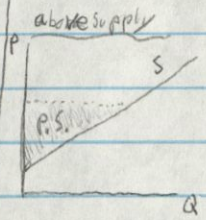
under Demand

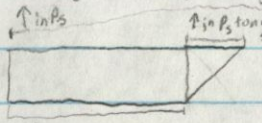




Producer Surplus (PS) = amount a seller is paid minus production costs (min. P. willing to accept)

above supply



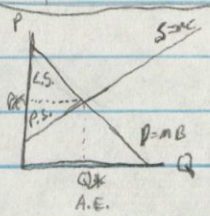


(P − MC)

Total Surplus: $T_S = CS + PS$

Allocative Efficiency: Q is A.E. if maximizes T.S. — NO DWL

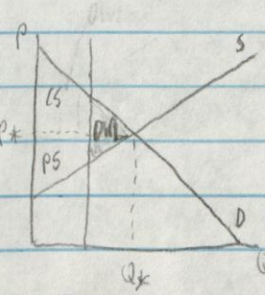
Perfectly competative: equilibrium Q* is A.E. (MB = MC)



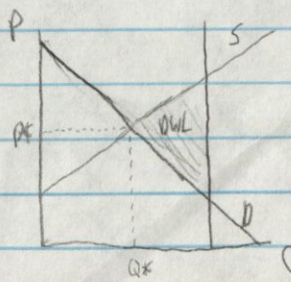
Efficiency — maximizes total welfare (economics)

equity — how to ÷

Dead Weight Loss (DWL) — loss in T.S. from an inefficient quantity



MB > MC — not enough sellers — shortage



MB < MC — not enough buyers — surplus

Ch 6 Policies

Policies

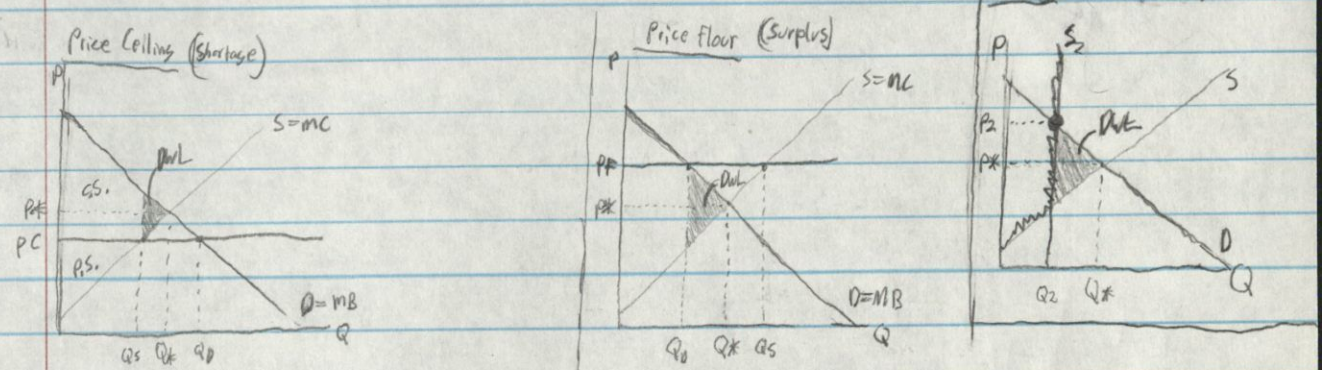
effective P.C. = Shortage — Price ceiling = legal maximum on price for a good (prevent equilibrium) ex: WWII price freeze

effective P.F. = Surplus — Price floor = legal minimum on price for a good (allow equilibrium) ex: min. wage.

Binding = below EQ

nonBinding = above EQ

Quotas = max Q of good sold



PC > P* (not effective) (Use case 1st come) non-binding

PC < P* (effective) (non-market allocation) Binding

PF < P* (not effective) non binding

PF > P* (effective) Binding

Consequences:

- inefficient allocation (DWL)
- wasted resources
- inefficient low quality

- inefficient allocation (DWL)
- wasted resources
- inefficiently high quality

Taxes

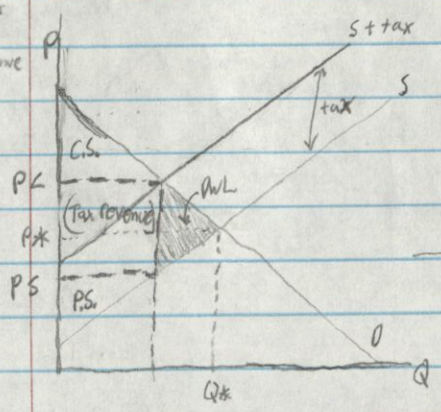
Excise Tax = consumer tax per unit sold

Price consumers pay = PC
Price sellers receive = PS
} tax wedge

in perfectly competitive market excise tax will be the same result for buyers & sellers

more elastic = want Δ behavior

more inelastic = raise $ more revenue



Calculate tax burdens

Consumers: PC − P* (pay w/ tax − pay w/o tax)

Sellers: P* − PS (pay w/o tax − pay w/ tax)

tax burdens falls on the more/relatively inelastic side either S. or D.

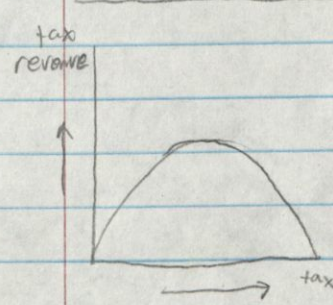
$\varepsilon_D < \varepsilon_S$ tax burden more on consumers

$\varepsilon_S < \varepsilon_D$ tax burden more on producers

$\varepsilon_S = \varepsilon_D$ tax burden split evenly

increased tax size = increase DWL

tax size & tax revenue — tax rev. = t · Q



Laffer Curve

people stop buying after price too high

Externalities

Externalities — cost/benefit from consumption/production that falls on 3rd party

neg. ⇒ usually over supply — pos. ⇒ usually under supply

neg. Prod. E. = ex Pollution — pos. Prod. E = ex R&D tech spillover

neg. Cons. E = ex Smoking — pos. Cons. E = ex flu shot

DWL points to Q A.E.

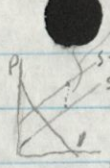
MC = marginal Private cost — MB = Marginal Private benefit

MEC = marginal external costs — MEB = Marginal external benefits

Marginal Social cost (MSC) — Marginal Social benefit MSB

MSC = MC + MEC — MSB = MB + MEB

(Socially optimal) allocative efficient : MSB = MSC



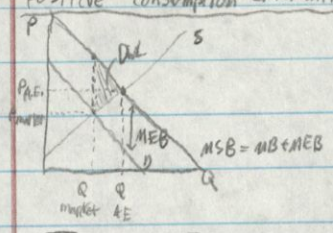
Ch6 cont. Policies — Solutions for externalities

① Regulations — certain activities, ex level of pollution
- no insentive to reduce pollution beyond regulated level
- not reduce pollution @ lowest level.

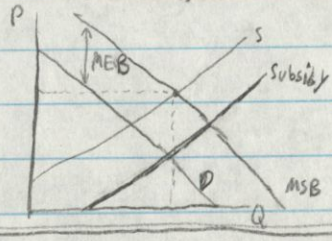
② Corrective taxes (Pigovian tax) - set tax = MEC, most efficient achieve level of poll. @ lowest cost

③ Cap & trade — can achieve a level of pollution @ lowest cost "efficiently"

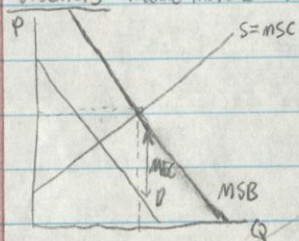
Positive consumption externality



Subsidy (permit subsidy) give producers a dollar amount per unit produced. Set subsidy = MEB



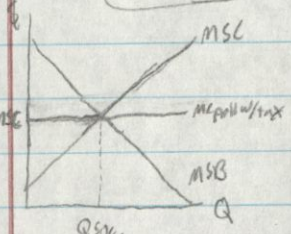
Vouchers income increase that can only use it for certain goods set voucher = MEB



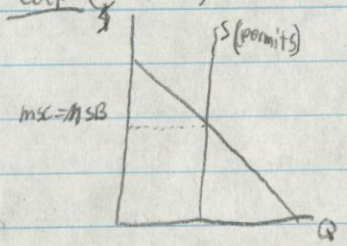
* Patents/copyrights only 1 company use product to inc. MB to cover MC — overall helps MSB

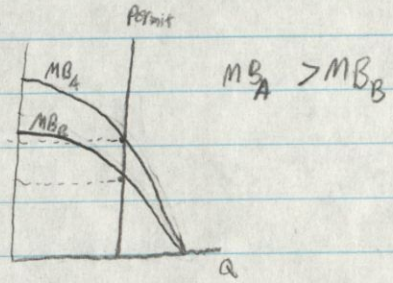
Taxes = price tool Optimal Tax (per unit tax) set tax = MSC @ socially optimal Q

Taxes (price tool)



Cap (quantity tool)

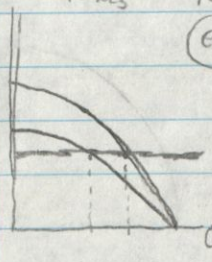


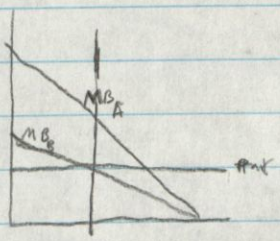


$MB_A > MB_B$

not efficient the cap tells no A.E. but not @ lowest cost.

Taxes reduced Pollution @ lowest cost (efficiently)





$MB_B < MB_A$

A offers $\$ \leq$ 1 permit

B values 1 permit $\geq \$\$$ of B

Coase Theorem: well defined property rights and no transaction costs private bargaining reaches soc. opt. outcome

transaction costs: costs incurred in process to come to agreement (think airplane seat reclining) (paying-off loud music neighbor)

Public Goods + Common resources

excludable = indv. can be prevented from using it nonexcludable = an indv. can't be prevented from using it

Rival (in consumption) = 1 persons use of a good dec. Q available for others ex: catch fish, buy shoes

nonrival = 1 persons use of a good does not dec Q available for others. ex: electricity, cable tv.

	excludable	non excludable
Rival	Private car, bike, coffee	Common resources fish, public parking spot, trees "free coffee"
non-rival	Club goods/ natural monopoly Cable tv, electricity, internet	public goods public park, nat. defense, lighthouse

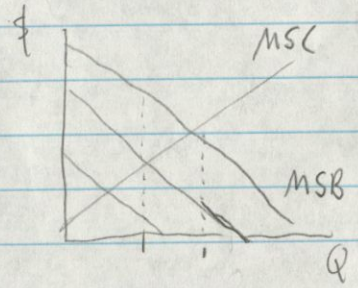
ex's Public Goods

Soc. opt. outcome is when MSB = MSC

MSB = sum of all parties MB @ fixed Q

Free Rider problem ← recieve benefits w/o paying

inefficiently low Q for public goods



Solutions for public goods

(1) Donations ex: WPR

(2) Sale of by Product ex: (WPR commercials)

(3) Private contracts ex: f.O.A.

Common Resources ex congested non-toll road

tragedy of the commons = No inscentive to prevent depletion + overuse

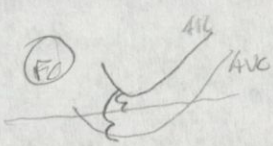
Solutions for Common Resources

(1) regulation

(2) Taxes

(3) Cap & Trade

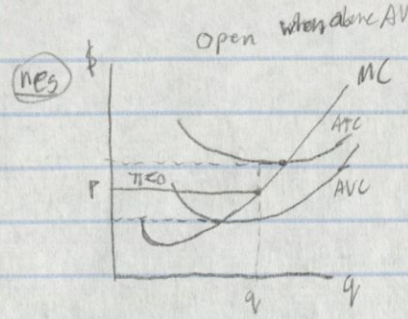
(4) Property rights

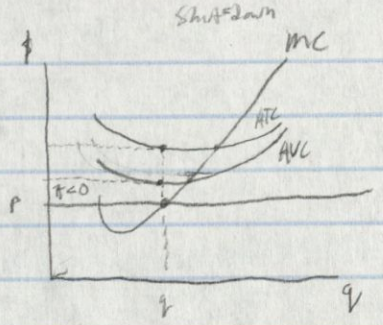


When below AVC

Shut down

Open when above AVC





Could stay open or shut down - whats the smlr. loss,

$P \geq$ min AVC, stay open $((q \cdot p \geq AVC \cdot q) = TR \geq VC)$ $MR = MC$

$P <$ min AVC, shutdown $((p \cdot q < AVC \cdot q) = TR < VC)$ $q = 0$

if $\pi = 0$, $P =$ minATC, no incentive to exit/enter

in SR π max quantity $P = MR = MC$

In SR
- no entry & exit,
- fixed # of firms
- assume firms are identical

$Q = n \cdot q$

In LR
- free entry/exit
- $\pi = 0$ b/c of ↑

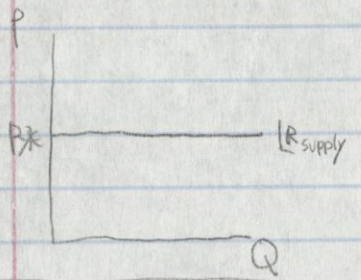
if $\pi < 0$ in SR
- $P <$ minATC

in LR firms exit, which incr. P

if $\pi > 0$ in SR

$P >$ minATC

in LR firms enter, which lowers P



q^* = producing output @ lowest possible cost (ATC min) = production efficient

perfectly competative
- in SR: $P = MR = MC$ (no markup of P above MC)
- in LR: $P = MR = MC =$ min ATC $\pi = 0$ production efficient

---

Monopoly - One seller • no close substitutes • barriers to entry • price maker

barriers to entry: b/c control of resources

economies of scales: over a relevant region single firm has lower costs to supply a good/service to entire market than more than 1 firm

Artificial Barriers: lobby to keep prices better for firm

Licensing - Ex Single trash company for a town

Patents/copyrights: intellectual prop. / specific goals no allow other companies to sell.

π max rule = $MR = MC$ * not a price taker, price maker *

$P < MR$

$MR > 0$, ↑TR ($\downarrow P, Q\uparrow$) elastic ($E_D > 1$)

$MR < 0$, ↓TR ($\downarrow P, Q\uparrow$) inelastic ($E_D < 1$)

$MR = 0$, $\Delta TR = 0$ ($\downarrow P, \uparrow Q$) unit elastic ($E_D = 1$)

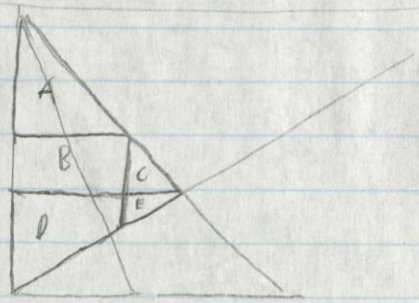
MR slope is 2x as steep as demand for monopolies

monopolies no worry about SR & LR problem — P_m is max price for Q_m that buyers will buy $\pi = (P - ATC) \cdot Q$

P.C. = allocative efficient $(MB = MC)$ monopoly = $Q = MC = MR$ not production efficient (has DWL)

$P_m > P_{PC}$
$Q_m < Q_{PC}$ } monopolists restricts outputs & raises price

$P_m > MC_{Qm}$ in LR monopolist earns π



Monopoly	Perfect Competition
$CS = A$	$CS = A+B+C$
$PS = B+D$	$P.S. = D+E$
$DWL = C+E$	

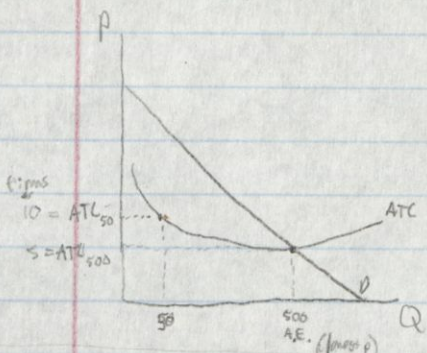
Price discrimination — charge dif. $ to dif. indv. or groups for same good. Ex: senior/student discounts

- must know buyers WTP & prohibit resale

Perfect price discrimination — sell same goods @ dif. prices (WTP) for e/ individual Ex: car dealership, tuition

- all Total surplus (TS) is Producer Surplus (PS) $PS = TS$; $CS = 0$ Allocative efficient

Natural monopoly — economies of scale over region, single firm has lower cost of producing for a market than 2 or more firms Ex: utilities



high FC & low MC

TC far

π is distance btw P & ATC subset to D

Marginal Cost Pricing: force monopolist P = MC = produce Q.A.E. (net $-\pi$) will exit in LR, so given subsidy

① Public ownership Policies towards monopolies - ex U.S. Postal service

② anti-trust laws breakup monopolies ex AT&T split

③ offer exclusive contracts

④ Do nothing — to allow P & D incentive

Summary

$P_m > P_{PC}$
$Q_m < Q_{PC}$ } monopolist restricts outputs & raises Price

In SR/LR $\pm$ or 0 π

$P_m > MC$ (markup over MC)

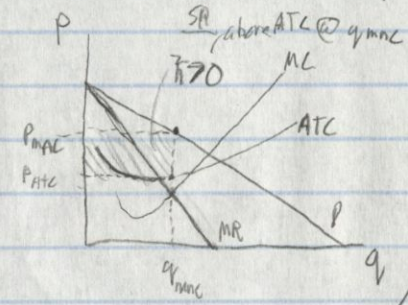
Monopolistic Competition

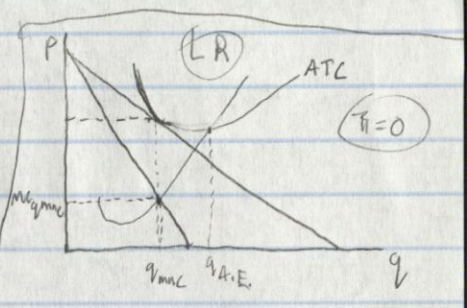
many sellers, free entry & exit (no barriers to entry), product differentiation (similar)

Differentiation factors Quality, Price (tradeoff btw Price & Q) marketing (advertising, location)

Demand is downward sloping

in LR $\pi = 0$





Firms - π in SR → firms exit

inc. D for existing firms

D becomes mo' inelastic

Firms + π in SR

firms entry

dec. D for all firms

D becomes mo' elastic

- not production efficient ($q_{A.E.} - q_{mnc}$)

not allocative efficient markup over MC

$P_{mnc} > MC$

Con	Pro
Advertising • manipulate tastes & preferences artificial product differentiation charge higher P	• informing consumers on substitutes available
• make D mo' inelastic	• make demand mo' elastic (charge lower P, b/c demand)
• impede competition entry	• promote competition

- firms plug signal to push people to leave to produce — ads are costly ↑ inc ATC

- $P_{mnc} > MC$ • not Allocative efficient • not production efficient

in LR: $\pi = 0$ (free entry & exit in LR)

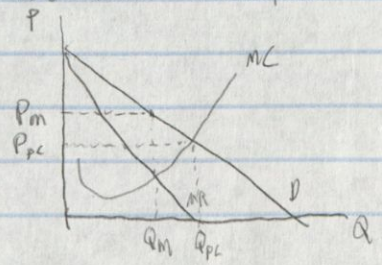
Oligopoly (closer to monopoly section) smaller # of larger firms

- small # of larger firms • Actions of firms are interdependent — possibility of collusion (mult. firms across monopolist)
- barriers to entry ex: controlled resources, legal, artificial

Duopoly: oligopoly w/ 2 firms could collude as 1 monopolist Q_m & P_m (split) — anti-trust laws to prevent collusion

$Q_M < Q_{OL} < Q_{PC}$

$P_{PC} < PC_{OL} < P_m$



Game Theory

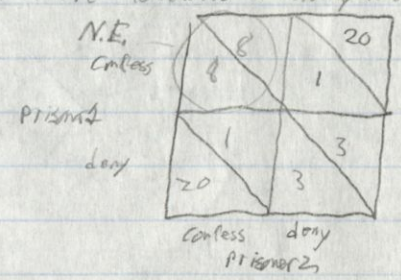
• max ↑ goal ① players ② rules ③ strategies ④ pay of matrix ⑤ equilibrium outcome

(A, B) Nash equilibrium: if A is best choice for player 1 when player 2 chooses B. & B is best choice for player 2 when player 1 has A

for all examples rules are: no communication, simultaneous choice, one shot

Prisoner's Dilemma – players make it hard to achieve a mutually beneficial outcome. Allowing communication overcomes problem

Strategy: confess or deny



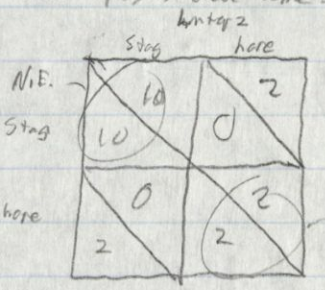
P1 confess, P2 confess
P1 deny, P2 confess
} dominant strategy

P2 confess, P2 confess
P2 deny, P2 confess
} dominant strategy

N.E. is (confess, confess)

Coordination Game N.E. occurs where players chose same strategy.

stag hunt, 2 hunters strategy hare or stag



H1 stag, H2 stag
H1 hare, H2 hare
H2 stag, H1 stag
H2 hare, H2 hare

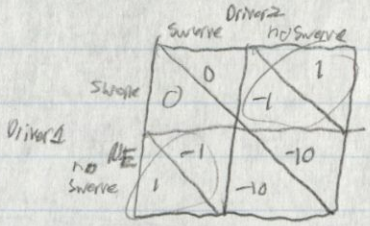
(stag, stag)
(hare, hare)

2 N.E. (stag, stag) or (Hare, Hare)

no dominant strategy

Anti Coordination Game: N.E. occurs where players choose opposite strategies

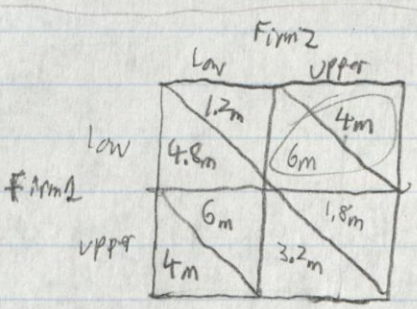
chicken, 2 drivers, swerve or not.



D1 swerve, D2 no swerve
D1 no swerve, D2 swerve
D2 swerve, D1 no swerve
D2 no swerve, D2 swerve

N.E. (swerve, no swerve)
(no swerve, swerve)

Ex: 2 firms
high & low quality coffee grinders
firm 1 more popular
Grt. demand for Low end product



F1 low, F2 high
F1 high, F2 low
F2 low, F1 low
F2 high, F1 low
} no dominant strat
N.E.
} dominant strat

We know F1's dom. strat. = low

F2 maximizes by doing a high (opposite)

Test #3 review

if FC then its SR
MR = P in perfectly competative

economic π = Total revenue (TR) − total cost (TC)

accounting π = TR − explicit costs

Total cost (TC) = explicit costs (outlay of cash) + implicit costs (no require outlay of cash)

π = Profit

economic π ① $\pi > 0$ profits ② $\pi = 0$ break even ③ $\pi < 0$ lose money

Production 2 inputs Labor (L) & Capital (K)

In Short Run (SR) − time period @ least 1 fixed input Labor is variable, Capital is fixed

Long Run (LR) − time period when all inputs variable

Production function = relationship btw Q of inputs & Q outputs of a good (Output (Q) = Total product (TP)) $f(K,L) \rightarrow$ output $Q = f(K,L)$

Marginal Product (of Labor): (MP_L) = Δ in total output from Δ mo' labor unit $\frac{\Delta TR}{\Delta L} = \frac{\Delta Q}{\Delta L}$

comes a point where Δ mo' labor unit = minimal ΔQ

Law of Diminishing MP = all else equal, MP will dec. as Q input inc.

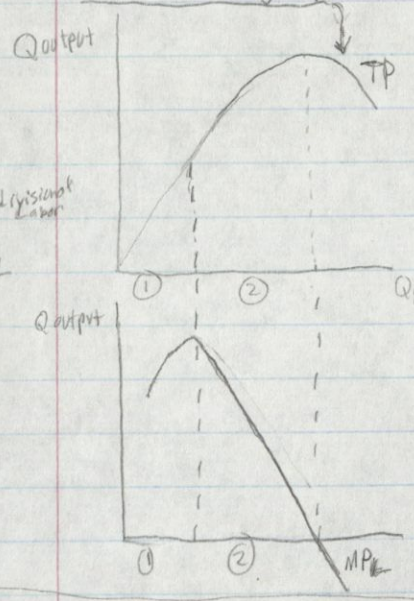
Average product $(AP) = \frac{Q}{L}$ (output per worker)

Fixed Cost (FC) = costs no vary w/ Q of output (constant)

Variable cost (VC) = costs that vary w/ Q of output, $(VC = w \cdot L)$ w = wages

$TC = FC + VC$

① Specialization & Divisional Labor
② diminishing MP_L

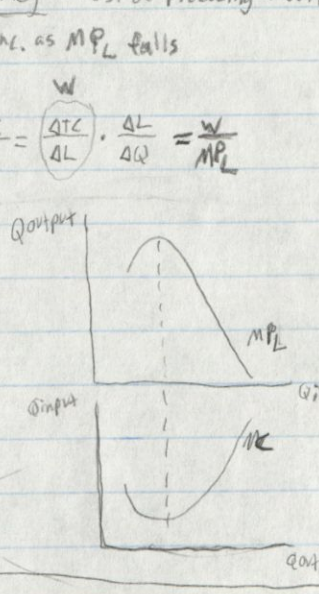


Marginal cost (MC) = Cost of producing additional unit of output

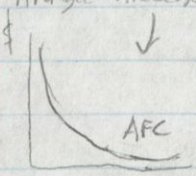
$\frac{\Delta TC}{\Delta Q}$ inc. as MP_L falls

$\frac{\Delta L}{\Delta Q} = \frac{1}{MP}$

$MC = \frac{\Delta TC}{\Delta Q} = \frac{\Delta TC}{\Delta L} \cdot \frac{\Delta L}{\Delta Q} = \frac{W}{MP_L}$

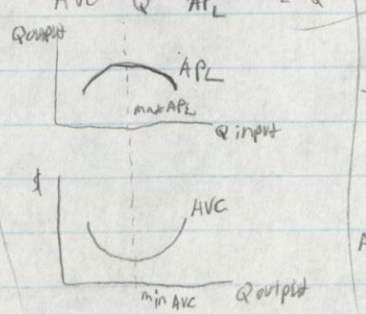


Average Fixed Cost $(AFC) = \frac{FC}{Q}$



Average Variable Cost (AVC) $= \frac{VC}{Q}$

$AVC = \frac{VC}{Q} = \frac{W}{AP_L}$ $AP_L = \frac{L}{Q}$

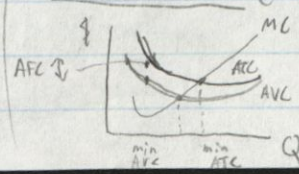


$ATC = \frac{TC}{Q} = AVC + AFC$

$AVC = \frac{VC}{Q}$ $AFC = \frac{FC}{Q}$

$MC = \frac{\Delta TC}{\Delta Q}$

Average total cost $(ATC) = \frac{TC}{Q} = \frac{VC + FC}{Q} = AFC + AVC$



MC > AVC, AVC ↑ (pos. slope)

MC < AVC, AVC ↓ (neg. slope)

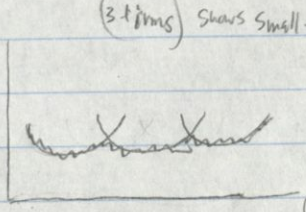
MC = AVC, ΔAVC = 0 (0 = slope)

MR=MC

Long Run all inputs variable FC=0 TC=VC

(3 types) shows small-large expansion

LR = long run



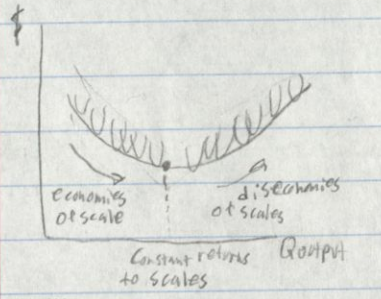
Long Run

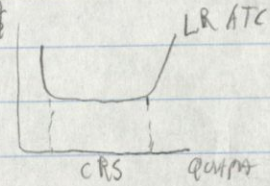
economies of scales: (LR) ATC falls as Q rises b/c specialization & division of labor

diseconomies of scales: (LR) ATC rises as Q rises • inc. coordination problems

Constant Returns to scales (CRS) = (LR) ATC no Δ as Q rises.

production efficient = produce @ lowest cost = CRS_{min} of (LR) ATC





Concentration Ratio (CR) = sum of Market shares of top 4 firms in industry

Herfindahl Hirschman Index (HHI) = sum of squared market shares around 0 — 10,000 shows concentration of market

Perfect Competition (PC) — many buyers & sellers • sell identical products • free entry/exit of market • price takers

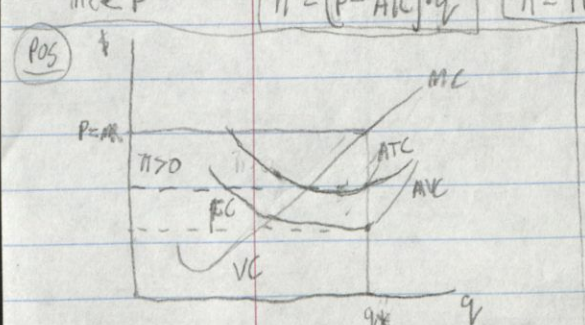
Marginal Thinking — marginal Revenue (MR) = additional revenue from selling one mo' unit

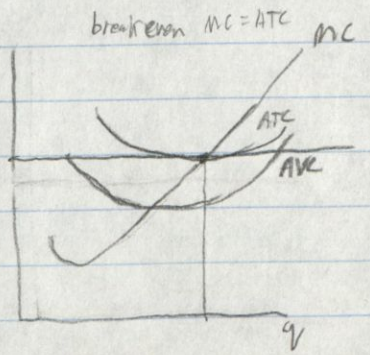
$MR = \frac{\Delta TR}{\Delta q}$ only in (PC) does MR = market price

MR > MC, keep producing ↑q to ↑π / MR < MC, ↓q to ↑π / MR = MC stop q. π max rate max q

MC < P

$\pi = (P - ATC) \cdot q$ $\pi = TR - TC$





Add mo' pictures

Geo

Doppler effect – wave length inc. in frequency towards a fixed point, and Dec. in frequency leaving a point (observer)

① Expanding Universe Theory – doppler effect Red shift = further away Blue shift = coming towards

Hubble's law – galaxies mass is proportional to velocity.

② Big Bang Theory – fixed amount of energy/matter in universe. Hydrogen forms 2 sec into it.

B. B. Nucleosynthesis – fusion of protons = elements w/ low Atomic #'s (He) – causes Nebula's – gas clouds.

Stellar Nucleosynthesis – higher atomic #'s form inside stars.

① fusion – sml. nucleouses fuse. ② Neutron capture + decay – from supernova's Neutrons are made

③ Nebular Theory – universe is 13.7 billion yrs, Earth is 4.6 Bya. made from protoplanetary accretionary disk (hot edges, dense; cool edges.)

Terrestrial planets – iron alloy core Gas Giants – H_2, He

Chem. differences		Physical differences
Core – Fe	Main abundant elements.	Lithosphere – crust, tectonic plates
Mantel – Fe, O, Si		Asthenosphere – solid rock (flows)
Crust – O, Si		Outer core – liquid, creates magnetic poles
		Inner Core – solid b/c of gravity or pressure

Minerals – solid, natural, crystalline, inorganic (no C) chem composition, structure.

Calcite = $CaCO_3$ Quartz = SiO_2

Polymorphs – same chem. composition, w/ diff chem structure. diamond v. graphite.

Silicates = ionic anion $(SiO_4)^{4-}$ always opaque Silicon-Oxygen Tetrahedron = 95% of crust minerals

Streak – color of dust. Luster – metalic or nonmetalic Hardness – Moh's hardness scale 1–10 (soft) (hard) fingernail scratch = 2.5 glass scratch = 5.5

Fracture – irregular breakage ex: Biting Bread – no weak points in all directions.

Cleavage – smooth planar breaking ex: slicing Bread – breaks @ weak spots.

Igneous Rocks

Freezing of Molten Rock

magma - underground (intrusive)
lava - aboveground (extrusive)

feldspar
K-spar, plagioclase — Felsic - high silicon; low Mg, Fe — Granite (mostly under continents [continental crust])
pyroxene, olivine, plagioclase — Matic - low silicon; high Mg, Fe — Basalt (mostly under oceans [oceanic crust])
amphibole, some qtz — Intermediate - some si; some Mg, Fe

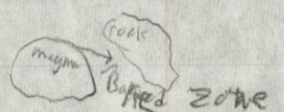
Melting Rock
1. Decompression - Δ in pressure (decrease) causes melting of magma. hot magma rises to shallower depth.
2. Addition of Volatile - add liquid or gasses (H_2O/CO_2) Breaks chem. bonds. = melting (ocean)
3. Heat transfer - rising magma melts rocks it intrudes (touches)

Xenoliths - rocks in magma that no melt. imbedded. ex: choco-chips

high — Matic — olivine, pyroxene, amphibole, K-spar
Temp rises
low — Felsic — Quartz

Partial melting - melt lower melt temp 1st (Felsic) then melt higher temp (Matic)
Vise versa for cooling

Intrusive magma goes into pre-existing country Rock



Tabular intrusions - flat plates Dikes (vert) sills (horz)
Igneous intrusions - Pluton/stock Blob 10_m - 10km
Batholith - Collections of nearby Plutons in area (100 km x 100km)

Classification

(1) Crystals - extrusive w/ fluid - fast = sml. crystals. intrusive w/ size/shape, water big crystals
(2) Aphanitic - crystals too small to see homogenous (extrusive)
Phaneritic - visible crystals coarse, (intrusive) heterogenious
Obsidian is made of qtz
Vesicular - preserves gas bubbles preserved. Fragmental pyroclastics ejected from volcano Tuff = volcanic ash

Wrap-up

Intrusive - underground → magma
↳ cools slowly = big crystals
Extrusive - above ground → lava
↳ cool quickly = sml. crystals.

Felsic high si (light) low melt
Matic high Mg, Fe (dark) high melt

Extrusive Settings

Volcanoes extrusive igneous setting. ex: eruption vent, Mat. built from product of eruption

lava flow

low viscosity - easily flow, flatten out Mafic Hotter, gas rich, crystal poor, less SiO_2

high viscosity - resist flow, slow Felsic cooler, gas poor, crystal rich, more SiO_2

Basaltic lava flow (Mafic)

sliding roll Pahoehoe - thin, crust forms ropy. b/c lava flows underneath it. aa - rough, flowing rough roll

Columnar Jointing - cracks on reg. pattern pillow lakes bottom of Ocean b/c so cold.

Volcaniclastic debris

Volcanic ash - powder - ash size glass frag. Felsic/Mafic Pumice/scoria - gas filled rock solidify @ vent

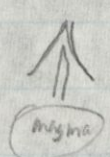
Lapilli - pea/plum size Blocks + bombs - lava cooled in air. apple to refrige size blocks chunks from walls of vents

Tuff - lithified ash Tephra, ash unlithified.

Pyro clastic flow - gravity driven avalanche of hot ash. + lapilli

Lahars fast moving flow ash-rich debris & water flows down streams

10% of magma is gass water CO_2 SO_2 hydrogen sulfide



Cutaway 

Cut in magma chamber

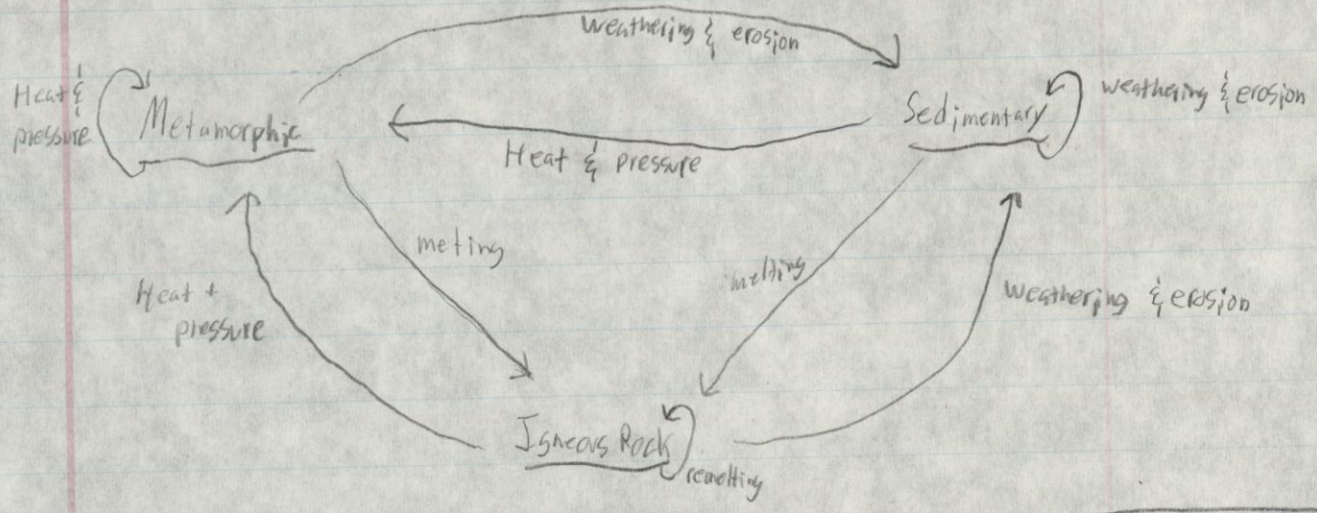
Cinder cones - cone shape piles of tephra (rubble pile)

Strato volcano - alt layers of lava + tephra. usually Felsic

lava dome - upside down bowl of crust heats up then pops to reform again Usually Felsic

Shield volcano - flat volcano Usually Mafic

Rock cycle



3 ~~ft~~	12 in
	1 ~~ft~~

3 ft = 12 in

unwanted units wanted to get rid of @ bottom.

Contour lines – connect points of same elevation

Contour interval – elevation diff. btw 2 adjacent contour lines

Index contours – every 5th contour line is labeled w/elevation

Mean sea level = 0

Rules of V's – apex of V or ^ points up stream

flows down

Transgression – water takes more shoreline

Regression – shoreline is "incr. further"

Soil horizons

O – layer of organic plant debris

E – lightly colored, leached soil

B – zone of oxidized clay/iron

C – chem. weathered bedrock

Sedimentary Rocks

All rocks erode by water/air

Sediment - loose fragments of debris

① Physical weathering - rocks breaks into unconnected chunks ex Rockslide

② Chemical weathering - reaction to destroy minerals if rock contacts air/water ex acid rain

① Exfoliation - Jointing like onionlike skites. Frost wedging - water fills in cracks expands if when open

Salt wedging - crystals grow in porous rocks to split it. Root wedging - plant push joints apart.

② Dissolution - dissolving in water Hydrolysis - minerals react to make new minerals

Oxidation - iron bearing minerals rust. → most stable after

Tropics have faster weathering than poles. Felsic last longer

Bioturbation - animals mix layers moles, plants Soil - weathering products mixed w/ iron

Granite - Chemical

K-spar - hydrolysis → clay

Qtz - Physical weather → sml grain size

Amphibole/Biotite (Mafic) - oxidation → hematite

① Clastic/detrital lithification loose sediments become together (beaches)

sed. transport → (rivers, wind) get sml. → depositions collection of loose sediment

higher the velocity of fluid = larger sed. can transport. except for glaciers

grains become more smooth as travel, & more uniform size

Deposition - Sed. gets out of transport. lithification - squeeze & adhesion

② Biochemical

limestone (calcite) $CaCO_3$ = shells of organisms reacts with acid. fossil limestone - white/gray shells in mud.

Quaquina - white/tan shell hash no mud. Micrite - gray/blk Shells from sea forams (plankton)

③ Organic

Plant remains over 50% carbon Coal rock

Coal only from plants.

④ Chemical

evaporates - salt water to leave salt flats halite/gypsum

Precipitates - dissolved material precipitate

travertine = stalagtite (chert in rocks)

Metamorphic Rock

toasting rock - solid form

Δ in form — protolith = parent rock

gneiss bits w/ white stripes — heat + pressure causes Δ's — hydrothermal fluids = hot water Δ's rocks w/ ions

heat rocks by burying them (foliated) — regional metamorphism ex: mtns form from earth plates

igneous intrusion brings heat to rocks (nonfoliated) — contact metamorphism ex: edges of plutons heat

Confining/lithostatic pressure — equal pressure in all directions ex: ocean

Differential/directional pressure — uneq pressure in direction.

Stress

(1) Compression - squeezing → ⬠ ← / (2) Tension - pulling ← ▭ →

(3) Shear — shear @ oblique angle

Foliation - alignment of crystals b/c of stress.

no Δ in composition

Recrystallization - Δ in size + shape - make interlocking texture puzzle look

Plastic deformation - Δ in shape of mineral grains.

pressure solution — dissolution + precipitation to weld grains together. w/ diff pressure

* Neocrystallization — makes new materials from solid-state diffusion of atoms in crystals

* chem diff

Metasomatism - hydrothermal fluid transport ions in/out = veins of precipitated materials.

↳ open if it has it to Δ chem compo. of Rock ; closed if it has no metasomatism

Grade - intensity of metamorphism - how hot/pressure

Low - low temp shallow depth, non foliated.

Intermediate - mid temp, mid depth

High — high temp, deep depth, better foliation w/ layers

Contact metamorphism = toasting rock from pluton edges

Protolith	metamorphic match
Granite	Gneiss
Limestone	marble
Shale	Slate
Quartz sandstone	Quartzite

* phase Δ is. mineral atoms become polymorph

ex: graphite to diamond.

schist - sparkly, fish scales

Maps

Latitude (equator) 0° – 90° (poles) N or S. of Equator

Longitude (prime meridian) 0° – 180° E. or W. of prime meridian

Ex: 35° 30' 23" N 1° = 60' minutes 1 minute = 60" seconds

equal offsets

widest @ middle

distance

Depression 

hill 

Topographic Contours line

Contour interval – Δ in elevation in 2 lines

rule of V's open in downstream direction 

steep slope ||| / gradual slope | | |

Reletive Dating

(1) Uniformitarianism – gol. processes today are similar to as in past ex: ocean MOR similar rates expand

(2) Superposition – oldest rock @ bottom; younger @ top.

(3) Original Horizontality – sed. rocks in flat strata. layers 1st, then tilting 2nd.

(4) Original Continuity – sed. rock layers deposited in continuous sheets. Layers span eroded gaps. accumulate layer then cut it.

(5) Cross-Cutting relationships – rock layers 1st, then cutting fault/intrusion 2nd

(6) Inclusions – if unit B contains pieces of unit A, then A existed before B

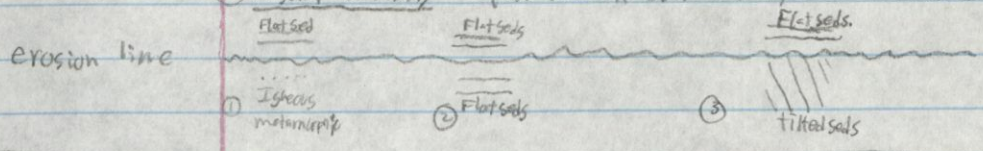
(7) Baked Contacts – intrusions cook edges of plutons. Cooked rock is older than intrusion

Unconformities – gaps in rock record. nondepositional (hiatus) or erosion

(1) Nonconformities – sed rock over igneous/metamorphic rocks w/ eroded igneous

(2) Disconformities – parallel layers of sed rock w/ missing (eroded) line.

(3) Angular conformity – flat sed rocks over eroded, tilted sed rocks other



Atomic # = # of protons Atomic weight = Σ protons neutrons Absolute Dating

Isotope = same element w/ diff neutrons

half-life – time for parent to decay to ½ size

Radioactivity discovered in 1896

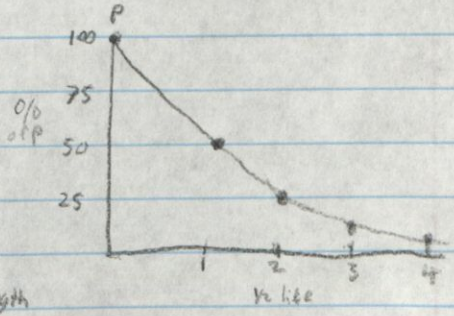
radiogenic parent atom decays to daughter stable

predictable, closed system for igneous/metamorphic

① ratio of parent : daughter

② ratio of % P, # ½ gone by

③ multi # of ½ lives by ½ life length



Fossil fuels - ancient organisms degraded in rock ex: oil, natural gas, coal

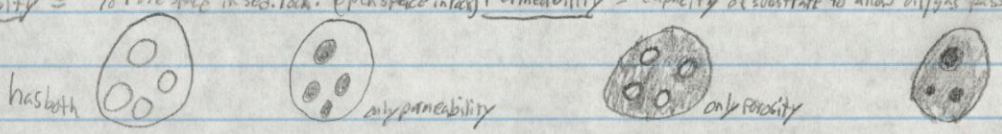
Oil & natural gas from marine settings. Hydrocarbon - carbon + hydrogen CH_4 Methal

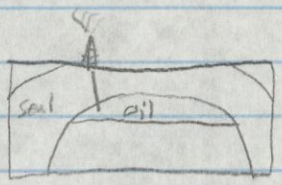
short chain - less viscous, more volatile ex: natural gas Long chain - more viscous, less volatile ex: tar

Oil & Gas	Coal
Plankton & algea	undecayed plant build up (trees) no oxidation
quiet water basins in deep oceans O_2 poor water	near shore environments deltas/swamps
clay/shale areas	heat + time + pressure Shallow Lignite - 70% C high moisture
pressure, heat, time	↓ Bituminous - 80-90% C compaction removes moisture & volatiles
	Deep Anthracite - 90-100% C low moisture low volatiles exposed

Carry in beds Reservoir rock holds/collects hydrocarbons easy extraction. Sed. Rocks looser than igneous/metamorphic porous

Porosity = % pore space in sed. rock. (open space in rock) Permeability = capacity of substrate to allow oil/gas passage (connection btw spaces)

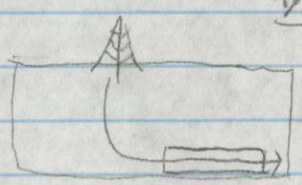




Anticlines are good traps for oil 1 barrell = 42 gal crude

Marcellus shale - low permeability

Hydrofraking fluid = 90% water 9% sand, 1% chem use pressured water w/ sand to blast cracks in shale beds to allow permeability. - gas flows out to rig



It could contaminate groundwater/rivers (burning water)

removing it or adding it to ground inc. magnitude/f of quakes.

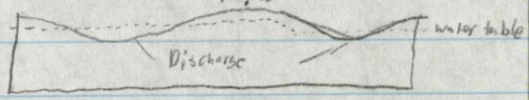
Strip mining blows off mnt top to get coal seam closer to surface. - safer for miners

Wast dumped in next valley - infects rivers/ecosystem

Global
Saline waters 97%
freshwater 3%
77% glaciers
22% groundwater

Ground water
water within sediments/cracks in rocks

in ground
- Unsaturated zone — air + water in pores not fully wet
- Water table — boundary of unsaturated to saturated — Of all the time — mimics surface topography — low elevation = low water table, high elevation = high water table
- Saturated zone — water in pores



recharge area — Surface water infiltrates aquifier → flows to → Discharge area - G.W. flows back to surface

Aquifer - layers of rock/sed w/ permeability to water. - Sand, sandstone, conglomerate, limestone
Aquitard - layers of rock/sed w/o permeability to water. - clay, shale, crystalline bed rock
Unconfined aquifer - water not confined, can rise to ground level. - water table could intersect surface
think ores — Confined aquifer - water sandwiched btw aquitards. Confined / seperated from surface

Perched W.T. ← sml pocket of water in unsaturated zone w/ aquitard bottom to hold it.

Potentiometric Surface - elevation water within a confined aquifer will rise in well - Oil gyser
Flowing artesian well - water flows w/o pumping.
Subsidence — too much water from ground → less water pores; mo' air pores = mo' sand compaction

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limestone bedrock w/ lots of G.W. — Karst Landscapes (Caves) - chem weathering dissolution of limestone landscape
Caves form from in path of acidic G.W.T. then it goes deeper underground to make air passage
dry cave - not actively forming — wet cave = active formation

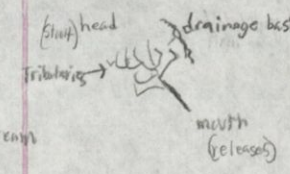
Speleothems
- stalactites = ceiling hangs (Soda straw build up of calcite) — stalactites
- stalagmites = floor formations (measure yrs. of climate wetness) — stalagMites

If connected = column.

Sinkholes (circular depression of cavern collapse), natural bridges, Dissapearing streams (surface streams to flow to underground)

Springs are natural seepage of G.W. to surface

hot springs 30-104°C
from deep G.W. heated @ depth to surface or G.W. heated near surface by volcanism



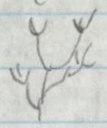
Trunk stream

Surface Water Streams

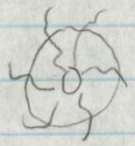
1-2° dip of sheet wash from rain into channels to lead to stream

Top Views

Dendritic (flat-underlining bedrock)



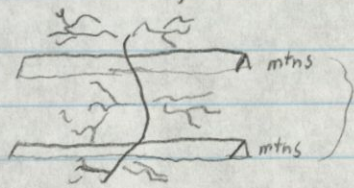
Radial



from volcano/most high center elevation

Joint - water collects in cracks (west US deserts)

Trellis



Divides blocks 2 or mo' drainage basins

Stream flow - how much water flowing in a stream Discharge (Q) volume per time ft^3/sec, m^3/sec

Q = velocity × Area (w·L)

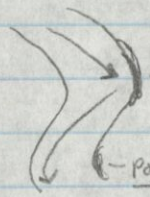
$\frac{ft}{s} \cdot (ft^3) = ft^3/s$

higher V. in middle of streams b/c water molecules pass other water molecules

Wider streams - slower b/c mo' surface or bottom friction

deep streams - deeper w/ faster

Curves/meander

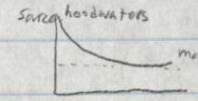


cut banks eroding (outside curve) eroding actively

Point bars deposition (sed.) (inside curve)

near source: steep slope, high velocity

near mouth: shallow slope, low velocity

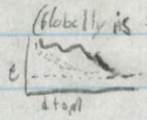


mo' erosion @ headwaters mo' dominant → transports → deposition along profile (near mouth) mo' dominant

Bed load - sand/gravel Suspended load - silt & clay makes it murky

Base level is lowest elevation stream erodes to. (Globally is sea level)

local base levels - lakes/ponds ect... bedrock



Ocean levels Δ

raised Base level = mo' sed. alluvium

lowered base level = inc. erosion

Urbanization takes away drainage space = mo' bad floods often.

Meandering - gentle erosion

Braided - high sed. during floods creates channel @ norm. flow - coarse sed

Deltas - fan of streams @ mouth drops off sed. to sea. Ox-bow lake - cresent from river point breaks - abiosynic (cool/brisk)

Recurrence interval # years of the discharge of given size occurs

$$R = \frac{(n+1)}{m}$$

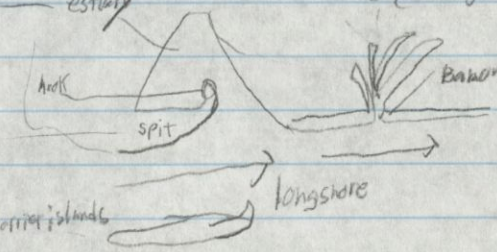
n = # of years of data - all years

m = rank (in set)

Shores

Fair weather - push sand onshore Storm weather - pull sands offshore

Salt + fresh waters meet estuary All waves come to angles Long shore - over all wave movement (parallel to beach)

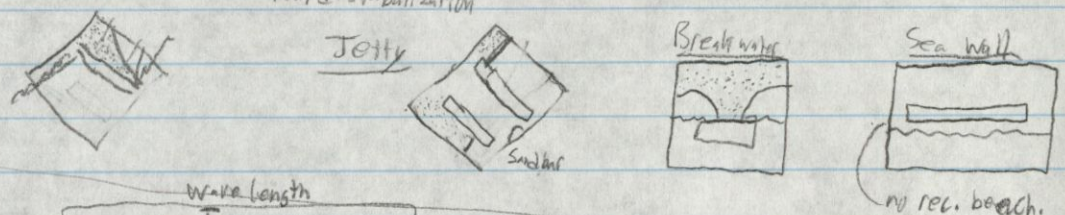


Bayhead bar (spits close estuary) bars off mouth of bay

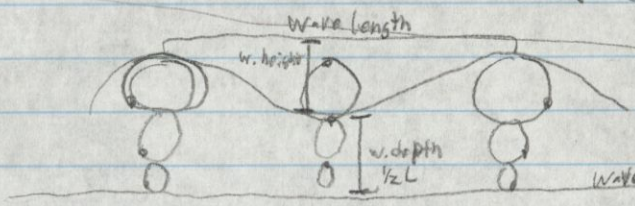
Down stream is hook Barrier islands move landward w/ sea level rise

Hard stabilization

Groyne Jetty Breakwater Sea wall



Convection cells



wave currents loss current = no' deep
waves on shore = no' height + shorter wavelength

Salt water ions from dissolved rocks in rivers (drop to world oceans) & volcanic gases from MOR's

Temp + salinity control it

Deep currents - homo-salts + no' cold. Shallow currents - hetero-salts + no' warm lower salinity in poles; no' salinity @ equator

wind controls it

Coriolis effect - current direction b/c of earth rotation. gyre lrg. circular pattern N. hem clockwise S. hem counterclockwise

Thermohaline circulation

Upwelling - rich deep saline water gets up to surface, water pushed away from shore ex: Ca coast

Downwelling - surface water falls to deep water, water pulled towards shore

Oceans are CO_2 sinks 50% of humans CO_2 in last 50 yrs absorbed by oceans - low ph hurts forams

Shoreline formation/evolution • material of shore • Tidal range • weather, wind, climate, climate Δ • tectonic activity

US. E. Const Shorelines - Passive margin

Submergent - "drowning coastlines" ex: sea level rises ↑ tectonic sinking. barrier islands, sand bars, salt marshes, bays lagoons

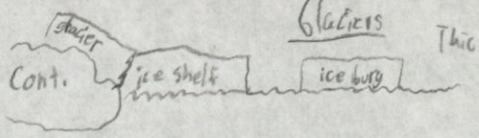
US. SW. Coast - Active margin

Emergent - "exposing the coast" ex: sea levels fall ↓ tectonic uplift, cliffs, topo relief steep, straight coastline

- make U gouge not V gouge

Glaciers

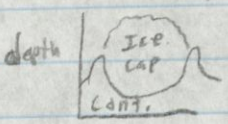
Thick ice masses. accumulation + compaction of snow



(1) Alpine (in valley) - smaller than ice sheets L > W like river

(2) Ice Sheets (cont. glacier) covers 10% of Earth Greenland 1.7 mil km² Antarctica 13.9 mil km²

cross-sectional



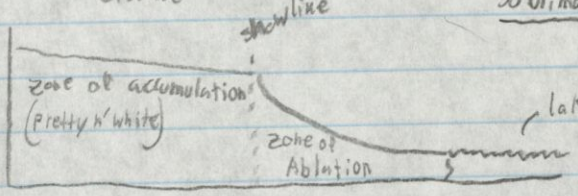
weight compacts cont.

Accumulation (add ice) snowing

Ablation (loss of ice) melt, calving, sublimation

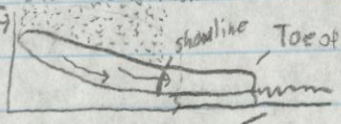
melting - solid to liquid Calving - chunks of ice break off

Sublimation - solid to gas from A in temp of ice & air

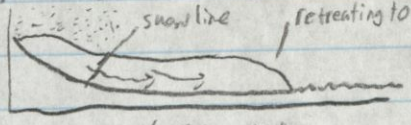


lakes show that glaciers loose mass or melt water ponds

Glacial advance mo' accumulation than ablation - lower snow line



Glacial Retreat less accumulation than Ablation - higher snow line



horn - peak of mountain. has cirques on side. Arête "A" shaped steep ridge btw 2 glaciers & horns

Cirque - bowl-shape depression to collect snow (zone of accumulation)

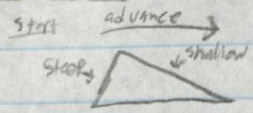
Crevasses - wrinkling meet up of 2 or mo' glaciers

Lateral Moraine - where glaciers edges scrap Arêtes

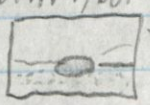
Medial Moraine - 2 glaciers meet their lat. m's. to form middle moraine.

Terminal Moraine - debris deposited in front of glacier. marks furthest spot of glacial advance

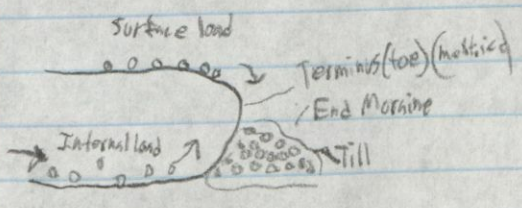
Ground Moraine - debris accumulated under glacier. creates kettle lakes



Esker - shape of river, but has sod ice around it.



erratics - boulders carried by glaciers, then left alone.



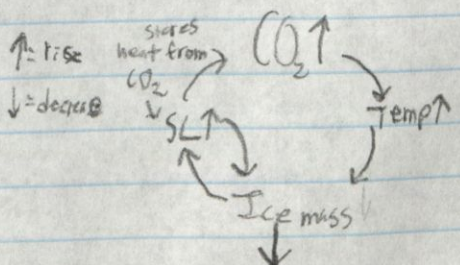
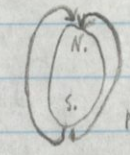


Plate Techtonics

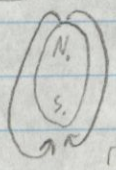
① Continental Drift - they move ② Sea floor spreading - explains how they move

Alfred Wegener Ger. meteorologist. 1915 published: Pangea - Super Continent, map evidence - shorelines (diff) match up w/ same rocks on both. age/type of rocks on mnt belt for many countries line up.
paleoclimate indicators - old iceage icecaps cover conts b/c used to be together. Fossil evidence similar finds near diff. conts. 1924 - rejected problems: no cont, seafloor is static/old.

Magnetic poles / Geo-Axis

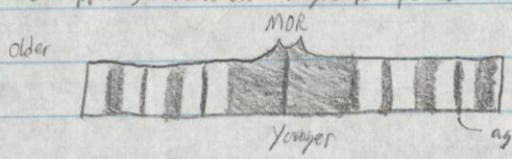


Normal



reversal

magnitite mineral is magnetic (in oceanic matic lava) it aligns w/ Earth's poles. (magnetic)
when lava cools (@ MOR's) it permanately records location/orientation of Earth's dipoles.
- Same applies for when magnetic poles reverse. new lava aligns to new poles.



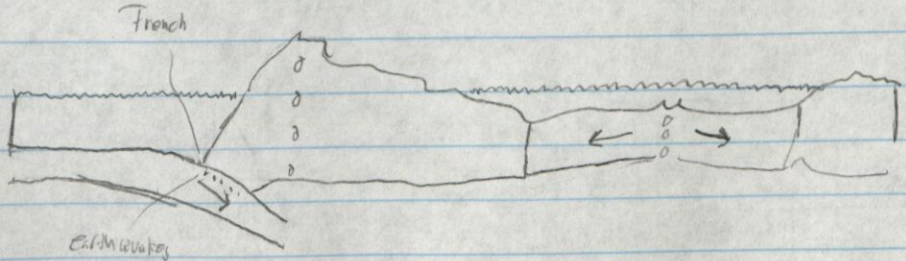
- Parallel lines of attraction to MOR, but offset in opposite directions for the reversals
age it to compare to current MOR age = rate of plate movement.

1963 Vine, Matthews, & Morley Connected seafloor spreading & cont drift on magnetic reversals @ MOR's.

Oceans

WWII navy made sonar to learn about subs - used it to map ocean floors.
- found MOR's (Bilateral offset symmetry) largest continental mtn belt of young basaltic lava
atlantic MOR is 70,000 km.
- trenches discovered - cracks where plates subduct each other MORS, fracture zones
- abyssal plains flat, deep seafloor covered by micrite sediment. 30% of earth's surface.

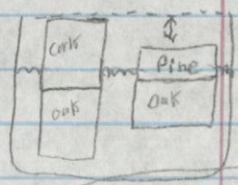
1950's Harry Hess - sea floors move & continents are passive
- continent has older mo' preserved rock.
- Subduction always melts oceanic plate to form volcanoes that make mtns.



pressure stress is on all sides

Plates

only include lithosphere (crust + upper mantle) float on asthenosphere



Continental lithosphere — mo' Felsic → Granite less dense mo' buoyant

Oceanic lithosphere — Mafic → Basalt mo' dense less buoyant — always subducts b/c mo' dense

Volcanic MOR's + Shallow quakes

45% (1) Divergent plates move away from each other. tensional stress exMOR's

Mor Oceanic-oceanic or Cont-Cont rifting

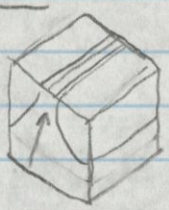
45% (2) Convergent plates move towards each other. Compression stress subduction cont. collision zone

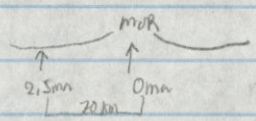
oceanic-oceanic, cold subducts · oceanic-cont, subducts · cont-Cont collision forms mtns

10% (3) Transform plates smear/shear each other, Shear stress side to side.

Any combo. Shallow Quakes

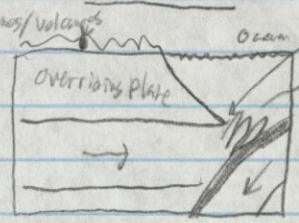
(1)





Rate of motion = distance / time

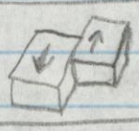
(2)



Sedimentary accretionary wedge. scraps sediment

Wadati-Benioff zone (WBZ) = zone of shallow/deep quakes on down going plate, older ocean further from MOR's

(3)



Fracture zones open individually

Triple Junction — 3 plates meet

Hot spots — Concentrated volcanoes form from deep plume @ fixed position. not associated w/ PB direction of older volcanoes is direction of plate movement. ex: Hawaii

US W. Coast — Active Margin — edge of continents next to plates lots of activity no Cont. shelf

US E. Coast — Passive Margin — " not a lot of geo activity broad shelf.

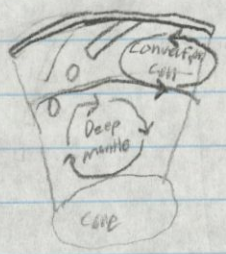
Continental Rifting — start of divergence. rift basins = lakes crust thins out to reveal volcanoes to create oceanic basalt. floors

Collisions of Cont litho — meeting of Cont lithosphere forms mtns shut down volcanoes ex: Himalayas

Lithosphere - crust + top upper mantle rigid rock Asthenosphere - rock, solid, flowing plastic deformation

(1) Convection — shallow - upper asthenosphere
deep - whole mantle involved

(2) force hot rises, cool sinks



(2a) Ridge-Push - gravity push lithosphere away from hot MOR
MOR cool it flattens b/c of gravity. MOR's create mo' land.

(2b) Slab-pull - cold lithosphere sinks downward force during subduction by gravity.

Mtn Building

Orogeny - mtn building event Stress - force acts on rock causes → Strain - Δ in rock b/c of stress

(1) Ductile strain — plastic deformation, smooth continuous deformation squeezing ex: twizzler

(2) Brittle strain - deformation til' break ex: kit kat bar

(1) Compression / (2) tension / (3) shear Stress = Force/area force = mass/acceleration

Convergent (1) → ← Shortens crust, mo' vert. Crustal root develops to make higher by buoyancy
Subduction - volcanic mnts (upper) Colliding - regional metamorphic mtns.

Divergent (2) lengthens crust thins it. Sed. melt builds up. Vert. downward
MOR, rift zone mtns crust thins + stretches

Transform (3) creates Strikes and faults horizontal movement

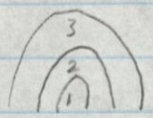
Exotic Terrane — offshore volcanic islands, arcs ocean plateaus frags. of cont. crust.

Accretionary Orogeny - mtn building thru attachment of exotic terrane to overriding crust.

Deformed Rocks (folded Rock)

plastic flexible
ductile deformation

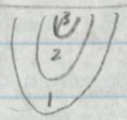
oldest 1 - 3 youngest



Anticlines - arch (∧-shape) fold. limbs dip from hinge.

Strike = parallel to contact

dip perpendicular to contact.



Synclines - U-shape trough-like limbs dip towards hinge

"smile when sign"

Shows direction of bed tilt.

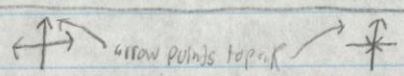
Points do younger beds.

Plunging - fold hinges @ angle

top view

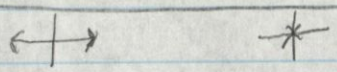
nonplunging folds hinges are horizontal

top view



Plunging Anticline

Plunging Syncline



Nonplunging anticline

Nonplunging Syncline

Dome like Anticline

Igneous intrusions put pressure to face up.

Older in center

Basin like Syncline

Meteorite/basin sinking Older outsides

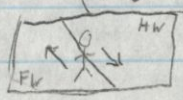
Low dip angles

35° or less

All from Brittle deformation

Normal faults

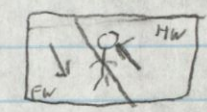
(tensional stress)



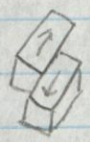
Dip slip faults Use disc as hands @ angle of fault

Reverse faults (thrust)

(compression stress)



left lateral



right lateral

Strike-slip

Shear stress from transform boundaries

Imagine standing on one side then look @ direction of movement.

Flat-lying rocks if topographic lines and geo-contact are parallel. or offset

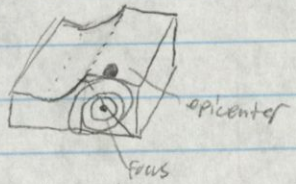
deformed Tilted rocks if topographic lines and geo contact cross.

Earth Quakes

episode of ground shaking energy

Focus: Underground location of rock rupture/split

Epicenter: point @ surface directly above focus

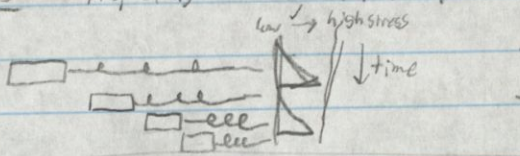


produces Seismic waves (energy) from tension, compression, new fault, slip @ existing fault, volcano eruption, landslide, meteorite hit.

Usually @ PB — MOR & transform – plates have shallow quakes

Subduction Convergent – deep quakes — reverse faults – @ accretionary wedge + thrust belt

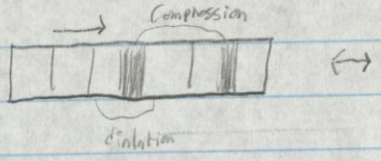
Normal faults – rifts, divergent Plates, failed rifts.



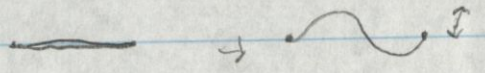
Seismic Waves

Horizontal Motion ↔ — Body Waves — Vertical Motion ↕

① **P-waves** – pressure waves. fastest. parallel to direction of travel. can go thru all of Earth 6km/s



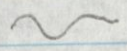
② **S-waves** – Shear waves. 2nd fastest. perpendicular vert. motion. only thru solids 3.5 km/s



bounces off liquid asthenosphere

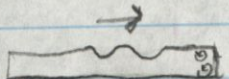
Surface waves

③ **Love-waves** – perpendicular horizontal motion. like shake. only thru solids @ surface



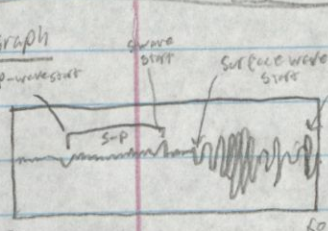
more intense closer to surface

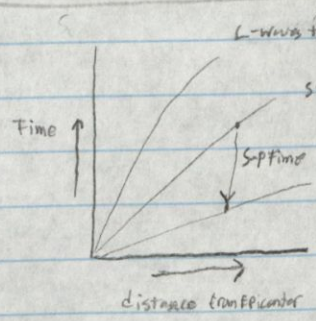
④ **Rayleigh waves** – rolling motion, eliptical. side view



like bowling ball.

Seismograph





at least use 3 stations to triangulate location

Closer to epicenter = more S-P time.

Intensity = damage quake caused.

Mercalli scale in roman numerals

Richter scale use arabic #s

Richter magnetude scale – on max amplitude on ground w/ motion on seismograph from center w/ distance from epicenter.

Ground shaking & displacements

Air pockets amplify wave energy (traps it)

1. Magnitude of Quake
2. how deep focus. (for building codes)
3. Foc wave ~ low /// high
4. substrate consistency / type of rock underneath.

Liquifaction – loss of strength in wet sand/clay from ground shaking. Waves pass thru substrate

Tsunamis

Sloshing water on grand scale. Normal fault (slip) creates dip to be filled w/water.

Reverse fault thrust pushes vert. motion upward to move it,

Wave ∫ inc near shore

$$\text{Speed of Tsunami} = \sqrt{g \cdot \text{depth of seafloor}}$$ (in Km/hr)

$g = 9.81\ m/s^2$ (gravity acceleration)

blind faults = faults that don't break earth surface.

First P-wave

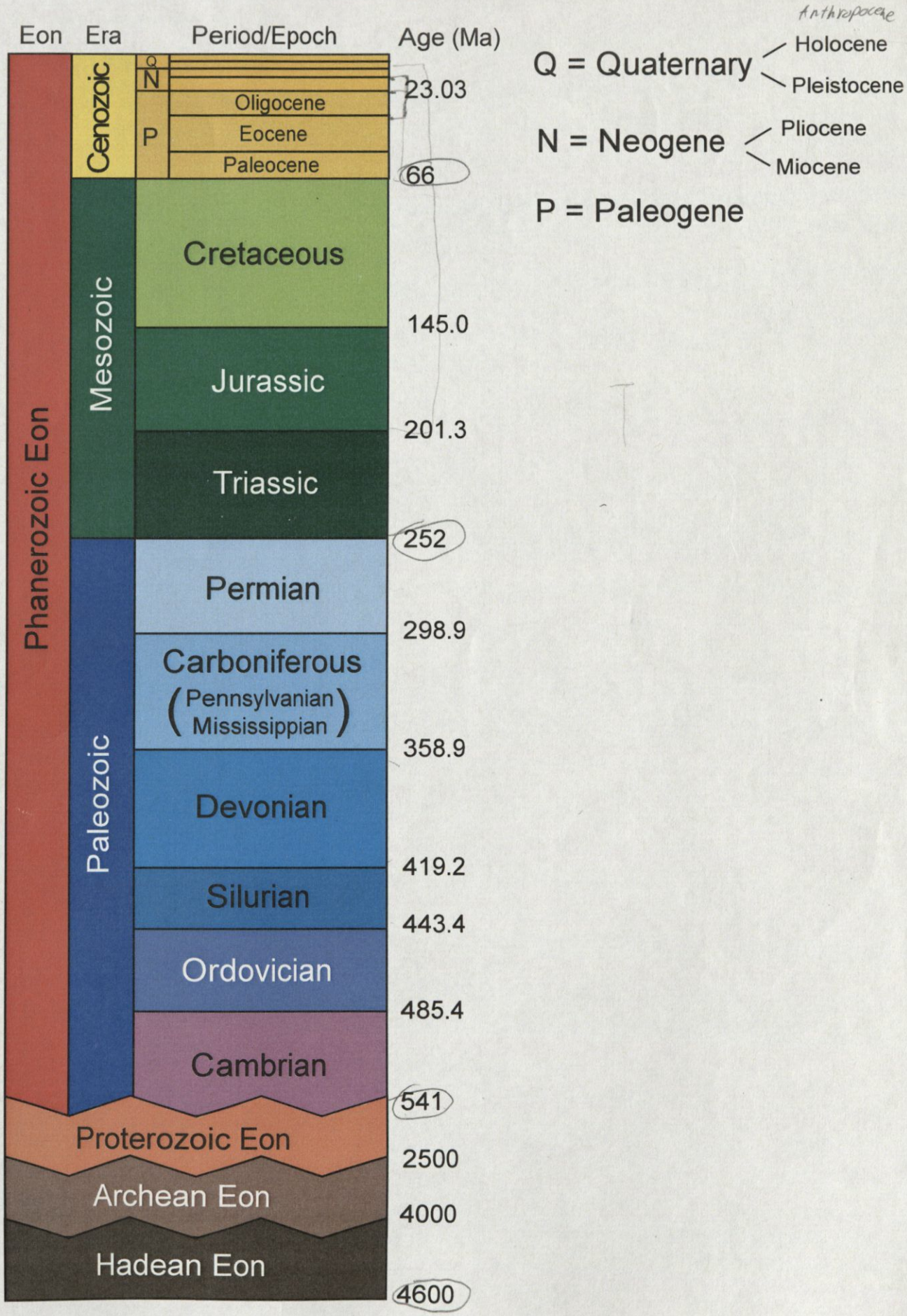
Compression ⟶ Dilation

$$\frac{\text{distance}}{\text{time}} = \text{speed}$$

Double conversions

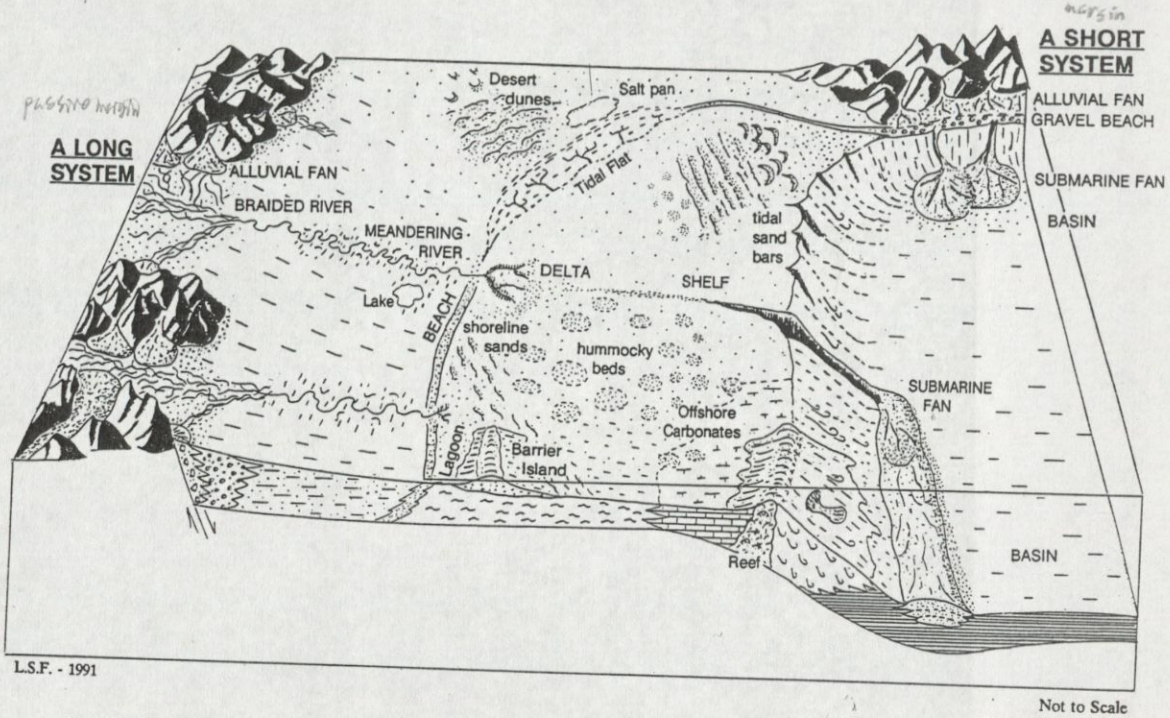
ex: $\frac{198\ m}{5} \mid \frac{1\ km}{1000\ m} \mid \frac{60\ s}{1\ min} \mid \frac{60\ min}{2\ hr} = 713.2\ km/hr$

Know all words + circles



FOLDOUT SHEET 2-FRONT

Siliciclastic Dominated Systems



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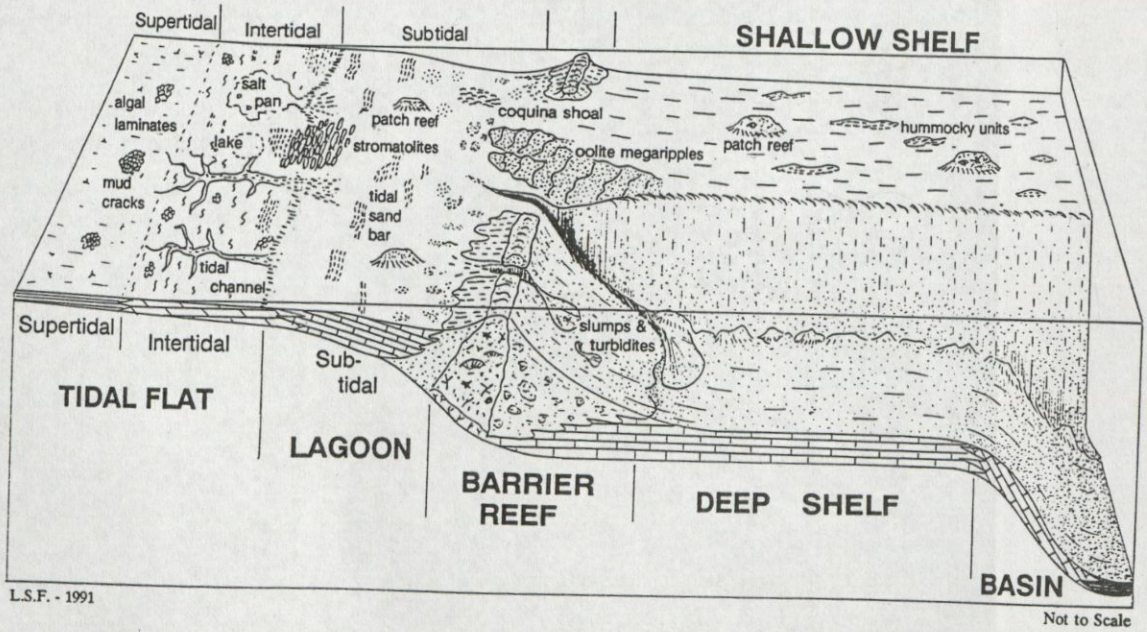
Not to Scale

Carbonate Dominated Systems



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Not to Scale

Fichter, L.S. and Poché, D.J.
Ancient Environments and the Interpretation of Geologic History.
2/e. © Macmillan. 1993

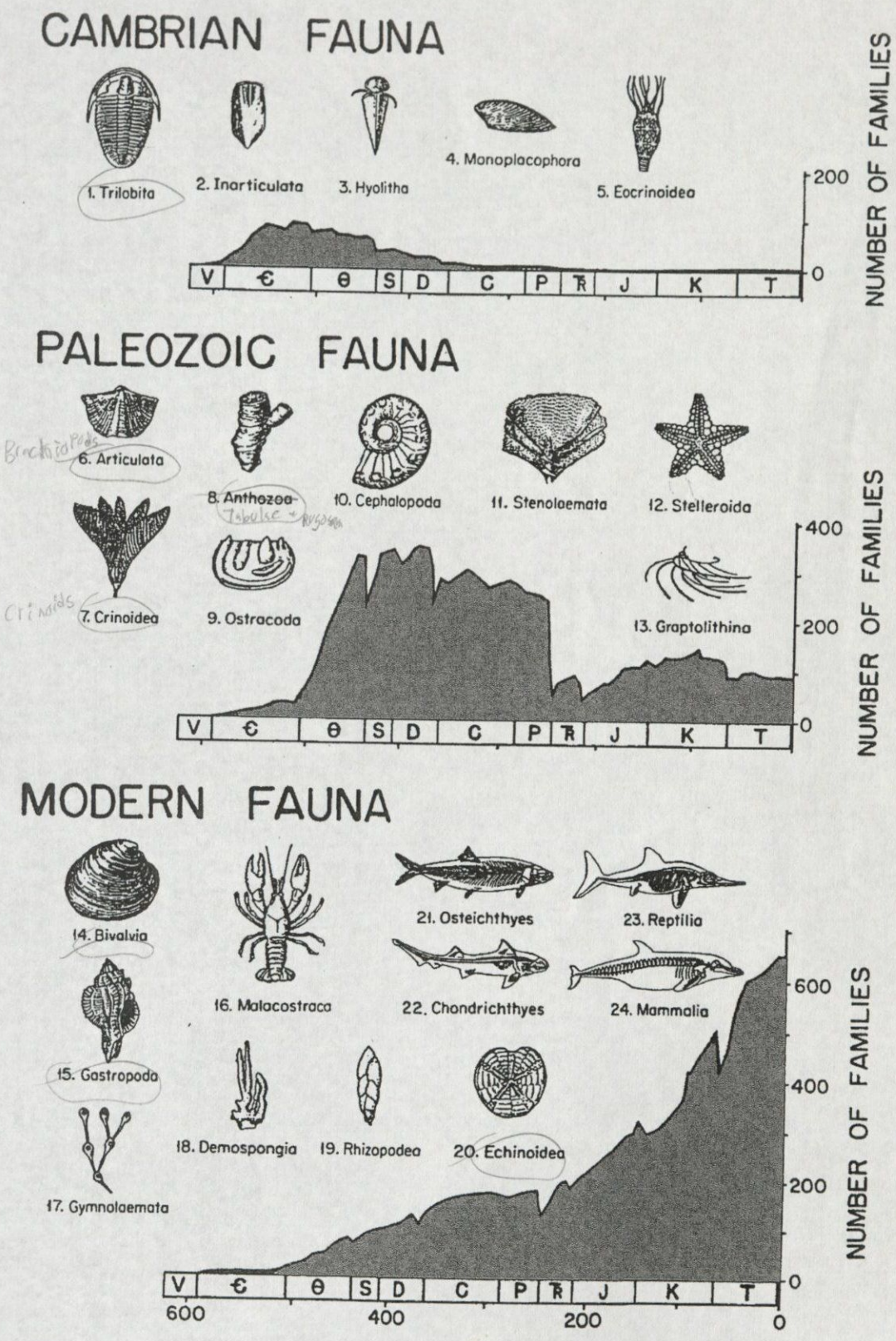


Figure 10.2 — The three "evolutionary faunas" making up the majority of the Phanerozic marine fossil record. Representative groups are illustrated and ranked by importance.

Depositional Environments and Facies

Ideal Clastic Dominated Long Systems

	TERRESTRIAL ENVIRONMENTS				TRANSITION ENVIRONMENTS					MARINE ENVIRONMENTS			
Typical Sediment Size and Texture	Alluvial Fan	Braided River	Meandering River: Alluvial Plain	Meandering River: Channel	Delta Complex (A complex of many sub-environments)	Lagoon or Delta Bay	Beach/ Barrier Island	Desert Dunes	Tidal Flat	Shelf: Storm Domin.	Shelf: Tidal Domin.	Sub-marine Fan	Deep Shelf or Basin Floor
Breccia	Very coarse; Immature												
Conglomerate	Crs-Med; Immature	Vry Crs to Medium Immature		Mud pebble at base of Point Bar			[Short Systems only]			Lag gravels	Lag gravels	Wacke Congl. in T_A	
Arenite	Very Crs; Immature	Vry Crs to Medium Immature		Med to Fn; some matrix common	In channel mouth sand bars	Storm wash in beds	Med - Crs; Very clean qtz sand	Fn-Md; Vry well sorted			Medium typical		
Wacke Sandstone			Fine sands typical	Typical	In levee and crevasse splay	Flood wash in beds			Typical	Fn - Med	Common	Fine-Crs T_{ABC}	
Siltstone			Typical	At top of Point Bar sequence	In levee and crevasse splay	Typical			Typical	Typical		Typical T_D	Common in small FUS
Shale			Usually silty		In bay fill	Typical			Typical	Typical		Typical T_E	Typical

Typical Rock Sequences Found in Environments

	L-BAR/T-BAR SEQUENCES			POINT BAR SEQUENCES (Floods fill in bays between channels creating delta plains; look for CUS)					HUMMOCKY SEQUENCES		BOUMA SEQUENCES	
Typical Color	Red, pink brown	Red, pink brown, gray-white	Red, tan brown typical	Red, tan brown typical	Gray to black; Mouth bar sands white	Gray to black	White	White, tan, reddish	Gray to black	Greenish to tan	Greenish to tan	Gray to dark gray	Dark gray to black
Sequence, or Most Typical Deposit	Massive deposits or thick CUS & FUS cycles. Unsorted/ unstrat. debris flows	Proximal; T-Bar; Distal; T-Bars	Laminated silts with thin crevasse splay and levee sands; beds often dip slightly	Ideal; A variant	channel; mouth bar; delta front; shelf; thick, overall CUS	BAY: Multiple FUS in overall CUS. LAGOON: Dark, organic rich muds	SWASH ZONE: parallel laminations gently dipping seaward. SHOALING WAVE ZONE: most kinds of ripples and cross beds	Very large scale X-beds; 10s to 100s meters high. Calcrete/ Silcrete soils	NO ONE IDEAL SEQUENCE: Wavy, flaser, lenticular bedding. Abundant small ripples, cross-beds. Oscillation ripples. Mudcracks. Herringbone cross-bedding	Proximal; Typical; Distal	Very large scale planar cross beds	Proximal; Ideal; Distal	Thinly laminates hales. CUS to thin silts at top. Bedded cherts
Other Typical Structures/ Conditions	Matrix supported gravel	Grain supported gravel; Imbrication sometimes	Climbing ripples typical	Many varients; HVLs and/or small X-beds may dominate sequence	Diagnostic: rippled, X-bedded chanel mouth bar cut by river; sometimes with coal cap	LAGOON: Storm wash in from barrier; lamination or planar cross beds	If gravel beach, gravel grain supported and imbricated	Grains very round & spherical Cross bed foresets strongly curved			May be confused with dune or braided river sand bodies	Matrix supported T_A gravel. Fluid escape stru, Flute, tool marks typical	Extreme low energy; Low oxygen
Typical Fossils	Rare trees or vertebrates	Rare trees or vertebrates	Plant fragments	Tree frags; vertebrates	Plant fragments; many kinds of sparse invert. types	Coquina. Brackish animals. plant frag.	Tree trunks; coquinas	Rare vertebrates		Diverse abundant marine inverts	Sparce marine fossils	Rare floaters & swimmers	Rare floater & swimmer
Trace Fossil Community			Scoyenia; root traces			Cruziana	Skolithos	Vertebrate tracks	Glossi-fungites	Cruizana abundant	Cruziana	Nerites	Zoo-phycus
Other					Slumps, loading, fluid escape common	Thin coals		Evaporites common	Evaporite in arid climates	Phosphate Glauconite	Phosphate		Phos-phate Pyrite

Ideal Carbonate Dominated Systems

	TRANS ENVIRON		MARINE ENVIRON		
Typical Allochems and Matrix	Tidal Flat (Super- and Inter-tidal)	Lagoon or Subtidal	Reef	Shelf	Dee She or Basi Floc
Reef Rock "Boundstone"		Small patch reefs	Typical, but see below		
Micrites	Pure; + oo-pel-& intra micrudite	Bio-(all kinds) Pel-Oo-	Compact mound or framework	Fossil- bio-/pel-micrites	Typical Sparce t
Sparites		Sparmic- and Micspar; Bio- Oospar			
Dolomites	Typical	In evaporite basins			
Chert	Nodular forms	Nodular forms		Nodular forms	Bedde forms
Salt/Gypsum	Typical in arid climates	Typical in arid climates			Shallo basins

Typical Rock Sequences Found in Environments

				HUMMOCKY SEQUENCES	
Typical Color	Light gray	Dark and light gray	Light gray	Lt to med gray, green, brown	Dark gray black
Sequence, or Most Typical Deposit	SUPERTIDAL: Mudcracks, Algal lamin. Pure massive micrite, Gypsum. INTERTIDAL: Sand bars, Herringbone, Flat Pebble Conglomerate, Wavy/lenticular bedding, Channels, Stromatolites	Large variety interbeded rock types. Micrites and biomic-dominant with storm wash in of calcarenite & oomic or oospar. Whole shell coquinas	Massive mounds of bound fossils without bedding. May be biomic-mounds or piles of fossil (spar) hash	Hummocky units of bio- and pelmic interbed with micrite OR thick beds of cross bedded bio-and oospar OR megarippled bio-sparmic & pelmic	Very eve millimete scale laminatio or massive micrites
Other Typical Structures/ Conditions	Broken abraded fossil-sand bars	Often interbed with clastics	Slumps, debris flows, and turbidites of fossil debris down front slope	Often interbed w/ shale/silt. Vry abndt diverse whole fossils	
Typical Fossils	Stromatolites, Algal laminates, Snails, Ostracods	Snails, arthropods, clams, sponges	Coral, Bryo Echinoderms Stromatop Red algae	Echinoderms, Cephalopods Coral, Brach, Arthro. etc	Rare swimming floating typ
Trace Fossil Community	Glossifungites	Cruziana prominant	Trypanites	Cruziana; vry burrowed	Zoophycu
Other	"Birdseye"			Glauconite Phosphate	Pyrite

Calcite - $CaCO_3$ Silicate minerals SiO_4

Historical Geol - earth his. in physical/biological evolution - sed rocks record it

Relative dating - accurate Abs dating - precise

basic Stratigraphy (layers)

Nicholas Steno (1638-1687) danish b. - wrote Unity Relative dating ideas

(1) superposition — older rock layers @ bottom - younger @ top

(2) Original horizontality — sed. deposits originally flat (horizontal) - inclined bed deformation after deposits

(3) Lateral Continuity — sed. layers erode overtime leaving gaps (thin layers) exposed (same layers)

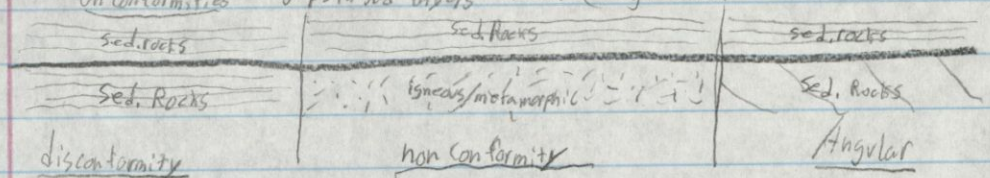
Neptunists — Werner (mineralogist) all rocks formed in grt. ocean think Nep. = sea

Plutonists — volcanic origin for primitive rocks

Unconformities

James Hutton (1726-1797) Scottish, Geol/Physician - Uniformitarianism — Geol. processes today are similar as in Past

Unconformities - gaps in sed layers b/c of (hiatus or erosion time



Study of layers

William "Strata" Smith (1769-1839) eng. engineer surveyor — use fossils to predict rocks into, — predicted rock thickness for excavations — mapped all of Eng.

fossil succession - predictable seq. of rocks by fossils

Georges Cuvier (1769-1832) Fra. anatomist, 1st vert. Paleontologist. - organism bone structure similar - biological Δ @ unconformities

Catastrophism — Earth's his. sudden, short global violent events ex: asteroid, flood volcanic, rapid climate Δ

Gradual processes — growth of glaciers, meandering rivers, recharge of aquifers, plate tectonics

Sir Charles Lyell (1797-1875) Eng. Geol. 1st Geol. textbook "Principles of Geol." - Darwin mentored it Both created natural selection - explained fossil seq.

(1) Cross cutting relationships - rock layers 1st, then fault/intrusion cuts them.

(2) Inclusions — pieces of "rock" in another rock, - the pieces are older

(3) Baked Contacts — intrusions bake surrounding rocks (contact metamorphism) baked rock is older than intrusion

west. Australia rocks 4.2 b.y. old

Alpha decay - rid of 2 neutrons & protons creates new element, Beta decay - rid of electron + neutrino to make 1 neutron a proton

½ life - time taken for ½ of parent to decay to daughter.

Igneous rock traps Zircons best inclosed system metamorphic & sed rocks - release it.

Sed. Rocks

Clastic - preexisting rock fragments biogenic/organic - shells/plant remains chem - precipitated from solution

weathering faster in warm, wet climates weathering makes sed rocks

Physical - ex tumbling, wind Chemical - rusting, dissolution, hydrolysis, breaks crystal lattice

4 Variables to I.D. sed. rocks

1. Composition - % of minerals present
2. Texture - grain size (clay, silt, sand, gravel), shape (Rounded, subrounded, subangular, angular)
   Sorting (well, moderate, poor) not visible mo' mature = mo' homogenous
3. Color - Red Beds exposed to O_2 after deposition subaerial (under air), Black beds - high organic content deep water (low O_2)
4. Sed. Structures - bed = single layer of sed. rocks. strata - several beds

   Mud cracks - wetting & drying delta swamps, tidal flats

   Ripple marks - ridges on beds. Asymmetric ripples - one direction of flow (river)

   Symmetric ripples - Bidirectional flow (waves) (tides)

   Cross-beds - show current direction herringbone - back & forth not in rivers

   Graded beds - seperate grain sizes decreases toward top (density factor)

   Turpidity current - from tectonic activity gravity driven, underwater avalanch

4 Sandstones (clastics)

1. Quartz Arenite ≥ 90% qtz, white-light gray, yellow-pink, well sorted & rounded tectonically stable env. (mature) ex: desert, beach, shallow marine, cont. shelf (beach sands)

"clean" no mud.

2. Arkose 40-50% feldspar, some qtz, & lithic frags. Pink-red-white, gray, Poor sorted angular eroded granite (immature)
   ex: Alluvial fans, rivers in cooler/dry climates

tectonic instability ⇒ Erosion

3. Lithic Arenite 5-50% lithic frags, qtz, some feldspar, salt + pepper gray, moderate sorting submature/mature
   ex: Alluvial fans, rivers, deltas, submarine fans (anywhere)

4. Wackes (gray wackes) >15% matrix (lot of clay), mostly qtz, light-dark gray (immature) tectonically active, poor-moderate sorting/rounding ex: turbidity deposits, rivers.

Depositional Environments

3 locations use 4 categories for sed. rock Fd.

① Terrestrial / Continental

Alpine Glaciers – ice/at wash river, poorly sorted, till deposits conglomerate, -immature

Mountain Stream – fast current, poorly sorted, variable minerals, conglomerate – immature

Alluvial Fans – fast-slow currents, poorly sorted, lots of feldspars, conglomerate, breccias, arkose

@ near falls of mnts. "Dry delta" high→low elevation (active area) -immature

Desert – current=wind, sed's well sorted, quartz, quartz arenite mo' frosted sands

Lakes – slow current, sed's. clay sized, clay minerals, shale

Rivers – current moderate, variable mineral sizes, fine flood plain, sand in bars, sandstone, siltstone, shale @ flood plain

Braided – near mnts. X channels (overlap) Meandering river – snake like

② Transitional

Marine Delta fast→slow current, lithic sandstone, siltstone, sub. env. = swamp, lagoon plant material becomes coal

Coastal Beach – bidirectional current, well sorted sed's. qtz mineral (arenite) mo' shells

Barrier Island – lots of lagoons created behind them, sand, mud, coal e/o bidirectional

lots of fossils

③ Marine

Shallow clastic – mo' current near shallow beach less @ deep, well sorted, well rounded siltstone/(cont. shelf)

Submarine fan – alluvial fan underwater. turbidity current in active margins both margins.

Deep marine – low current, clay, microfossil shells (fossiliferous limestone), calcite + qtz minerals

black shale, chalk, chert

Shallow carbonate marine – variable current. sed's = fossils, calcite minerals, limestone (reef),

Reefs like patches of calcite mud.

eroded granite = gruss

Facies

part of rock shows characteristic of depo. env.

from Mts → ocean (more) use 4 categories

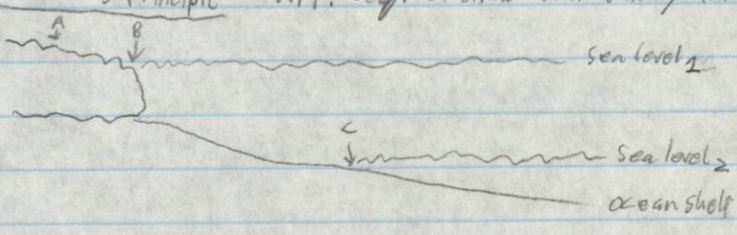
Key

- limestone
- clay/shale
- silt/siltstone
- sand/sandstone
- gravel/conglomerate
- igneous/metamorphic
- sand/sandstone with layers
- halite/evaporites

FUS = Fining upward sequence. Course seds @ bottom, finer @ top.

CUS = Coarsening upward sequence fine seds @ bottom, coarser @ top.

Walther's principle – vert. seq. of strata occur when w/ lateral adjacent env. (diagonal)



	T_1	T_2
A	river	Mnt. river
B	shore	river
C	shelf	beach

Transgression – sea level rises, coast migrates inland, FUS

Regression – sea level falls, coast migrates seaward, CUS

Causes	Transgression	Regression
Eustatic (global) sea level Δs	rise	fall
Tectonics	subsidence (sinking)	uplift
Sedimentation rates	low to negligible	high

main points

mo' affects on passive margins than active

Stratigraphy = mapping ancient (paleogeographic) Gol. use vert. sec. of rock (time), then lateral correlation in beds

Lithostratigraphy – match rocks by facies composition (litho) + stratigraphic position

Biostratigraphy – match rocks based on fossils

Chronostratigraphy – match rocks based on (abs) age

group
formation
member
Bed

Lithostratigraphic units – Gol. mappable w/ distinct layers above/below it separated by contacts

Method 1 pattern matching exact same seq. of rock layers in 2 locations

Facies Δ – lateral variation of rock Δs Pinchouts – seds spread out over whole basin tapers out

Shazam line separates it

Method 2 cycle matching look for CUS/FUS @ 2 dif. locations

– probably not exact match of grain sizes but similar trend.

Fossils

any evidence left by organism in past

Taphonomy – sci of fossilization lots to learn, but lots of gaps.

Scavenging/decay – soft tissue Breakage/transport – subject to current – hard tissues (bone) Burial/modification – hard tissues (bones, shells to be buried)

Decay (soft tissue)

1) supply of O_2 ($\uparrow O_2$ = faster)
2) Temperature ($\uparrow$ temp = faster)
3) pH (neutral pH = faster)

Breakage

Predators & scavengers – gastropods, wolves, crabs, vultures Decay – bacteria + fungi

Encrusters – corals, barnicles, worms (grow on surface & dissolve after death) Borers – sponges, worms, bivalves

Bioturbators – worms, clams, prairie dogs (mix sed. & burrow)

Chemical Breakage – original mineral composition & groundwater chem. Biochemical erosion from other animals

Corrosion/dissolution – ex: shells loose ridging, thin erose decoration on surface.

Mechanical Breakage – wind/wave currents Disarticulation – full skeleton is seperated

Fragmentation – broken up skeleton (shattering, sharp edges) Abrasion – wearing away

Burial + Modification

1) Aragonite ($CaCO_3$) – unstable, dissolves/recrystallizes easy – gastropods, bivalves, bryozoans, corals
2) Calcite ($CaCO_3$) – more stable, brachiopods, gastropods, bivalves, coral, bryozoans, trilobites, echinoderms, forams, coccoliths
3) Silica (SiO_2) quartz – easy to see, some sponges, radiolarians common as replacement mineral
4) Pyrite (FeS_2) – easy to see (fools gold) replacement mineral
5) Calcium phosphate or apatite (bone) – ($CaPO_4$) vertebrates, brachiopods, arthropods

Transport out of habitat In place/life position low current + rapid burial (dinosaur eggs in nest) remains in habitat – ex: shells whole

Depositional env:

energy of env. Low current = better preservation high current = more abrasion, more transport } Lakes best, flood plain, shallow shelf

Sedimentary rates Low = burial less likely, more disturbances high = rapid burial, more preservation }

Preservations

Unaltered remains – how it looked when alive, unaltered ex: insects in amber

Carbonization – thin film of carbon to give impressions ex: plants

Carbonization w/ mineral coating – preserve skeleton w/ good amount of detail.

Permineralization – minerals fill in pore space in wood/bone to petrify it.

Recrystallization – looses lots of details ex: shells become recrystalized

Replacement – ex: shell gets buried, calcite is replaced w/ other mineral common in Devonian age

Casts + molds Cast – external mold is filled in w/ sed.

Internal molds – get impressions inside shell

External mold – leaves impression of left behind in other sed.

sea level

epifaunal = live on sea floor

sea floor

infaunal = live below sea floor

geo ranges of spiecies

Biostratigraphy – fossils in specific strata

Index fossils – located anywhere, fast evolving (short window of specific dating) Geologically widespread, abundant, preserved well, easily recognizable

Graptolites = paleozoic   Ammonites = devonian–cretaceous   coccoliths = triassic–recent   forams = triassic – recent

Pollen = cretaceous–recent   conodonts = phanerozoic mo' browned w/ heat

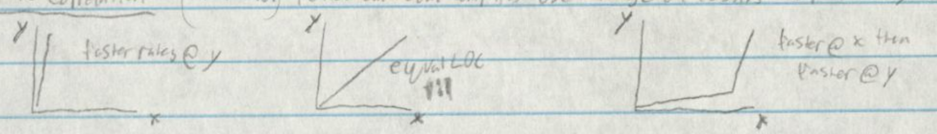
Biozones – unit of biostratigraphy. local/regional scale not always correlate w/ lithostrat.

Geologic Range – when show up + extinct   Assemblage Biozone – compare when spieces overlap w/ e/o spieces

faunal succession – predictable pattern of fossils. originate – evolve – extinct   rel. age dating

L.O.C. = line of correlation

Graphic Correlation (1964 devo.) petroleum + coal companies use range of fossils to predict layers of rock layers.



Paleo ecology

Geography + climate in past. marine fossils best b/c 75% ocean.

Pelagic – near sealevel (show water temp, salinity rates, current patterns)

Plankton – floating organisms, Nekton = swimmers

Benthic – sea floor ← and sed. rates   epifaunal – live on top of sed.   infaunal – live in seds

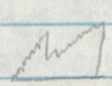
Pelagic [~~~ Sealevel

benthic ——— Seafloor

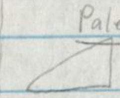
Paleo Geography   determine where oceans were in past – plate tectonics – fossil constraints

equator v. poles   Latitudinal diversity gradient – highest diversity (animal) in tropics declines @ higher tropics   land + sea.

Paleoclimate



Doubly serrate
serrated w/ sub-teeth
cool, temperate

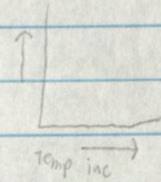


Entire
even, smooth
warm, tropical

Stomata density & CO_2

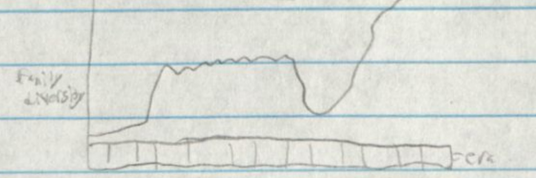
mo' pores = low atmospheric CO_2 levels = low global temp

less pores = high atmospheric CO_2 levels = high global temp



Sepkoski's diversity curve

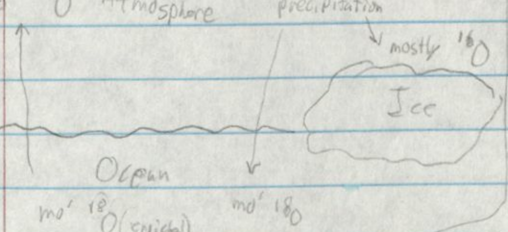
① Cambrian explosion
② Paleozoic plateau
③ Cenozoic increase



① Cambrian fauna (trilobites) / ② Paleozoic fauna (brachiopods, crinoids, Tabulate + Rugose coral) / ③ Modern fauna bivalves, gastropods (snails) equinoderms (sand dollar sea urchin)

Warm conditions = lower ^{18}O in ocean b/c mo' evaporate

Calcite records levels of ^{16}O & ^{18}O



Prokaryote – no nucleus, single cell.
Eukaryote – nucleus, single or mult cells.

Domain → Kingdom → Phylum

Eukaryota = most mult. cellular organism w/ nucleus

Bacteria = no nucleus, single cell (photosynthesizers)

Archaea – bacteria that live in extreme env.

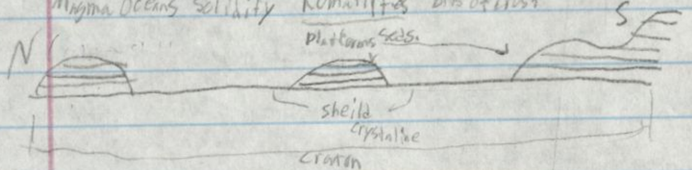
filter feed its old technique. – can't do it in tectonic active place b/c agitated sed.

Archean EON (4.6 - 2.5 Ga) includes Hadeon

Differentiation of Earth into physical and chemical layers

Magma oceans solidify Komatiites "bits" of crust

felsic melts 1st



metamorphism / plate tectonics
Granulite — gneiss from granite or cont.
Greenstone — Volcanic metamorphosed sed rocks — wilson cycle set up.

Ocean's formed 3.8 Ga evidence, Δ from acidic → alkaline

Atmosphere
- photochemical dissociation — ultraviolet light splits water molecules
- photosynthesisers
- Banded iron formations BIFs evidence of O_2 in atmosphere

life started in deep Oceans b/c ultraviolet radiation @ surface

release O_2 into the atmosphere
- Chemotrophs ← use sulfer not sunlight
- Anaerobic → harmed O_2 Prokaryotic — single cell no nucleus
- Stromatolites — layers of cyanobacteria mats + calcite mud.

Proterozoic EON (2.5 – 0.542 Ga)

Laurentia — 1st lrg. craton on earth N. Am craton
created by → Wopmay Orogeny = N. Am. Collision

Wilson Cycle — ① Rifting ② Sedimentation on passive margins ③ Subduction → collision

— thick BIFs.

Varves + Tillites — scratchings from glacial debris

Grenville Orogeny — Rodinia supercont. Appalachian + Blue ridge

no cont. @ equator reflect heat

Eukaryotes 2.7 – 1.8 Ga

endosymbiosis Theory — organelles started as symbients in prokaryotes

cyanobacteria = chloroplasts Eubacteria = mitochondria

sex. reproduction devo. + respiration devo.

Ediacaran fauna — (600 – 543 mya) Vendian in Aus. Rock

multicellular, bilateral symmetry + quilted body plans

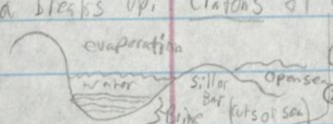
1st maj. radiation of life

Archean / Proterozoic

	Tectonic highlights		Life
Archean	– magnetic feild start – creates cont. + oceanic crust	– low O_2 levels in atmosphere	Chemoautotrophs – from deep ocean smoke vents (MORs) Stromatolites ← photosynthetic inc. O_2 levels → seen in Banded Iron Formations
Proterozoic	– wilson cycle devo. – wopmay orogeny – 1st supercont. Rodinia (Laurentia, N. Am)	– ice age tillites, evidence varves, dropstones	Ediacaran fauna – multicellular radiation of diversity, quilted body plans

Early Paleozoic (542 – 416 Ma)

Rodinia breaks up. Cratons of shallow epicontinental seas transgression (warming) / regression (cooling)



Appalachian 1-3
① Taconic Orogeny = Ord. U.S. E. Coast + vol. islands collide
② Acadian Orogeny – Dev. 370 ma. collision

③ Alleghenian orogeny – (320 – 290 ma) pennsylvanian collide w/ Africa Pangaea forms

Ouachita orogeny (Ozarks) pennsylvanian. continued 3rd's orogeny in S./W.

Cordillera N→S. mts. rockies + Sierra Nevada, Dev. – Penn. coast range on W. margin subduction

Cambrian explosion

Chem of oceans stable, lots of shelly animals. O_2 stable in atmosphere Brachiopods, trilobites echinoderms

lots of Lagerstätten (well preserved) in situ life. in Burgess shale. soft body preservation b/c turbidity currents

Breakup of Rodinia
① Rifting (divergent) tension stress normal faults rift basin rift volcano
② passive margins Sedimentation on edge of cont.
③ Subduction + collision Convergent compressional stress volcanoes, enthrusting mts.

Cratons – epicont. seas on sheild to layer platform seds – valuable oils + fossil fuels

Paleozoic plateau

Brachiopods, tabulate/rugose Corals Crinoids/blastoids as well as cam. fauna

Osteichthyes – bony ray fin lobe fined fishes Silurian.
3-chamber heart more O_2 to bld. sturdy limbs. hearing in air, waxy skin for moisture

Diapsids = 2 holes behind eye – reptiles
Synapsids – 1 hole behind eye – early reptiles + all mammals
} Pem.
reproduction w/o water amniotic egg (late carboniferous)

Bryophytes = mosses, liverworts, hornworts ordivician
Tracheophytes – vascular plants stems Silurian
} plants dec. erosion, inc. soil rates new habits lycopsids "scale trees"

Late Ord. extinction – trilobites, brachiopods, bryozoans, corals hit hard. Global cooling = ice caps growth glaciations

Late Dev. extinction – ammonoids, fish, conodonts hard hit low O_2 levels in ocean meteor impacts, glaciation

Late Per. extinction – trilobites, blastoids, tabulate, rugose = extinct Global warm to high CO_2 Siberian Flood volcanism acid rain Siberia

96% marine species dead.

Alleghanian = appalachian E. of Laurentia. Laurentia + N. African compression. final stage of Pangaea.
Dev. subduction on W. of Laurentia.

end per. maj. extinction climate Δ w/ lots of volcano fld. Cambrian + most Paleozoic fauna = gone

brachiopods, tab/rug corals crinoids/blastoids trilobites → gone

Mesozoic (251-65 ma)

Triassic, Jurassic, cretaceous

Breakup Pangaea - Tri. rifting, volcanism, normal faults, Atlantic + newark (NJ) basin Jur. Atlantic ocean opens to S.

early Cenozoic ; if final separation (50-45 ma)

modern plankton devp in oceans

Angiosperms - flowering seed plants

Tri - Laurentian shield (wes) had subduction. Jur.-Cret (E.) subsidence of atlantic costal plain. Jur.- epicontinental seas - evaporate deposits

Accretionary Tectonics - sml islands collide w/ west of Cont. Sevier orogeny - low angle thrust faults shear Paleozoic rocks from pre-Cam.

related to subduction

Laramide orogeny - high-angle reverse faults

Teleosts - ray finned fishes bony skeleton. } modern fauna: sclerectinian corals, molluscs, sea urchins + sand dollars

BD = Ornithischian (Herbivore dinos bird hipped) pubis points backward Saurischian (lizard hipped) (lead to T-rex leads to birds) Pubis points forward.

Adaptive radiation - inc. in diversity of organisms spread in highly varied eco. niches.

- diversification of teeth, lots of ear bones, whisker pits (mammals)
- lower jaw functionally single bone

Lobe finned fish - tetrapod lead to amphibians + reptiles.

4th extinction - late Tri. - hard hit Paleozoic inverts = Out ammonites, corals, marine, land vert, plants. Global cooling (cause), volcanism in Atlantic

K-Extinction

dinos, - lots of marine + all flying reptiles gone. ammonites, plankton + some benthic invertebrates

- meteor events chixculub crater Volcanism flds. basalts in India + Pakistan reorganized terrestial communities
- Global Cooling - made way for mammals.

Cenozoic (65 ma - Today) Synopsis

Seperate Pangaea (50-45 ma) early cenozoic

E. Passive margins (NJ) shales, sandstones (FL.) = mo' limestone (Gulf coast) = quartz w/ limestone

W. miocene uplift - normal faults - creates rockies 1-4 @ Cascade mts - volcanoes from subduction from Juan de fuca plate N. Am. (volcanoes.)

① Basin + Range normal faults ② Colorado Plateau pliocene uplift of flat Paleozoic rocks ③ Columbia Plateau - miocene volcanic flds. basalts

NV. + Ida Ut, CO, Az, NM. - looks like Grand Canyon OR + WA + ID magma intrusions b/c subduction

Ice Age = Labrador current in Canada to S. w/ gulfstream. mix Causes plants to shift S.

Cooling of Earth Surface

① Milankovich

Precession - Earths rotation axis wobbles (26,000 yr cycle)

Eccenicity - Earths orbit around Sun. (100,000 yrs)

tilt - Earths tilt to sun varies (41,000 yr)

② Albedo = reflectivity

Surface w/o snow or ice absorbs mo' heat

Surface w/ snow or ice reflects heat

③ CO_2 levels Precipitation

Mammals

mega faunal extinction probable due to meteor impact causes Ice age.

- animals can't adj to temp. fluc.

Mod. adaptive radiation: air, sea, land.

Monotremes - primitive, lay eggs; secrete milk, lower Cret. - recent

Marsupials - nurture young in external pouch (Cret. - R)

Dominant Eutheria - retain young for long time, feed thru placenta.

N. + S. America interchange b/w

lots of N. = dominate.

Evolution

pass genetic variations in pop.

Small scale – Δs in gene $ in pop. Macro scale – diversification of species from common ancestor

Darwin & Wallace – nat. selection = diversity. both had ideas of diversity + geography (naturalist)

1842 Darwin outline of nat. selection. 1858 Wallace sent letter to Darwin in same idea 1859 origin of species

(1) Random mutations of DNA = improper copying of DNA (2) Gene flow by location ex: grn. bugs in forest brown bugs in sticks

(3) Sex reproduction of new combos of genes in pop.

(1) Mutations = random Δs in DNA. (2) migration – new indv. move from 2 group to next pop.

(3) Genetic drift – Δs in gene pool of sml. pop. has random killing ex: predators, extinction

(4) Natural selection – non random better traits survive better @ one point in time

live longer = more chance to reproduce = more passing heredity = higher pop.

fitness = how many offspring can have Apoptations = features common in pop. b/c inc. fitness

Origination – lineages split Extinction – killing event.

Stasis – some species no Δshape w/ time ex: sharks Character Δ = some species Δshape all the time ex: Brachiopods

- transitional forms preserved in fossils

- Shared fossil adaptations

Epifauna – live on/in sed. benthic Infauna – in sed. benthic

Planktic – floaters @ mercy of currents.

Paleozoic (541–252 Ma) C O S D Carb P

Tectonic Timeline Taconic orogeny (collision) Acadian orogeny (collision) Ouachita orog. (collision) Alleghenian orogeny (collision – Pangea)

E. U.S.A Passive

W. U.S.A. passive After orogeny (subduction)

Platform (central U.S.A) epic cont. seas Salt domes

Bio Timeline Cam. fauna Paleozoic fauna dec

Paleo – invert fish – lobe finned fish move on land. – ray finned in sea

Meso – age of reptiles – dino lad – marine reptiles – flying reptiles

Ceno – age mammals (bats) from lizard hipped +

Geomorphology

weathering (aelian, fracturing (roots or ice), hydro, solar, chem) **Redder soil** = mo' old = hematite weathering **Black soil** = lack of O_2 & decomposing material

Soil – Natural material usually w/ horizontal layers formed in situ @ surface of earth. it is chem/physically/mineralogy/biological dif. from starting material

Top ↓ Down — process — C / A / B / C

17 elements needed for plants

C. B. HOPKiNS CaFé Closed
Monday Morning and Night See you Zoon, the Mg
(Cu (copper))

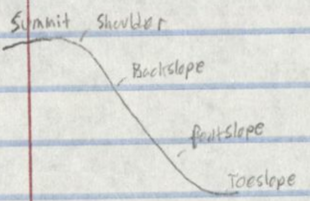
(Carbon, Boron, Hydrogen, Oxygen, phosphorus, potassium, Nitrogen, Sulfur, Calcium, Iron, Manganese, Molybdinum, Nickel, Copper, Zinc, Magnesium)

or CHOPPiN' SCuM COMMON Bicz

function of () Clorpt...

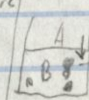
cl = climate O = organisims R = relief P = parent material T = time .... = chaos.

Hans Jenny (1899–1992) factors of soil formation f(Cl, O, R, P, T ....)



- O – **organic** > 90% of plant material can be thick or thin layers
- A – **mineral** > ± 90% minerals
- E – zone of Eluviation (bleached white sand)
- B clay – **zone of Accumulation** mo' red & mo' clay = older
- C – unweathered parent material
- R – unweathered rock **regolith** – loose, rocks, physically weathered.

Orange Apes Eat Black Card Decks (R)



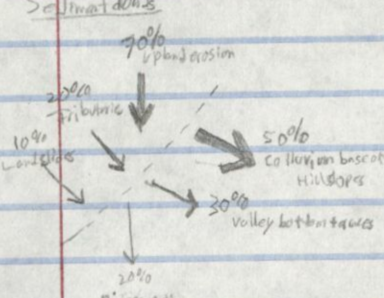
Crotovina – animal burrows in soil.

permeability – inter connectedness of void space   **porosity** – void space available in %

(Vertical) Soil Pedon – representative soil 3d profile of a (Horizontal) (@ a depth) **Catena** → sequence of soil at a sertain level depth

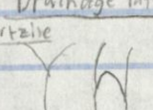
$Q_{in} - Q_{out} = \Delta S_T$ storage.

Sediment loads

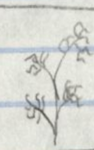


Drainage Patterns

Trellis (quartzite) • synclines • anticlines

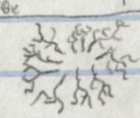


Dendritic (sandstone) • rates of uplift • bedrock type were ≈



Rectangular • karst landscapes (chem) w/ jointing.

Radial • volcanoes



Terraces are old flood plains

Strahler Method – stream order (from tributaries to distributaries) to bump up order ex: 2+2 = 3

Shreve's Method – stream magnetude **Knick Point** – abrupt Δ in slope ex: waterfall

$R_B = \frac{N_n}{N_{n+1}}$ N_n = no. of stream order

Capacity – max sed load a stream can carry.

Supply limited – no sed. added in it. mo' has higher vel. + more erosion.

Transport limited – lower velocity & low sed. capacity deposition occurs

Velocity

$$V = \frac{R^{2/3} \cdot S^{1/2}}{n}$$

slope; roughness → Manning Coefficient

$R = \frac{A}{\text{wetted perimeter}}$ hydrolic radius

Deeper depth = lower velocity

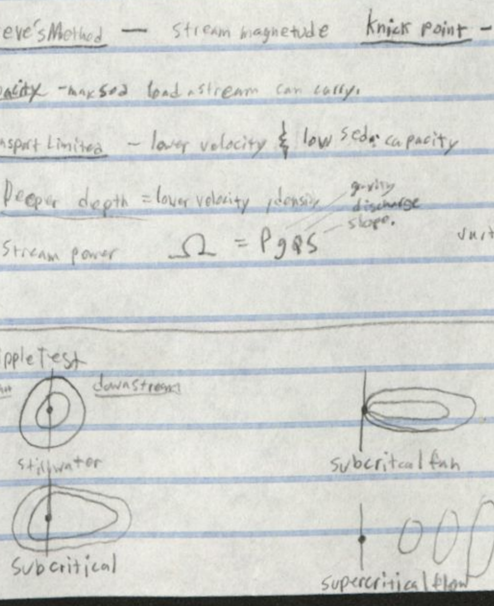
Stream power $\Omega = \rho g Q S$ (density, gravity, discharge, slope.)

Unit stream power $\omega = \Omega / w$ (lowercase omega; width)

Froude # $Fr = \frac{V}{D_g}^{\wedge .5}$

- $Fr < 1$ subcritical or tranquil flow
- $Fr = 1$ during critical flow
- $Fr > 1$ supercritical / turbulent

Ripple Test



Stone Test throw in stream — ripple: upstream (sub) / downstream (sup.)

pressure on bed to move sed.

Shear stress $T = \rho_w g D \sin\sigma$ — ρ_w = density of water, g = gravity, D = flow depth, σ = water surface slope in °

$T_c = T_{c^*} g(\rho_s - \rho_w) d50$ critical shear stress (size of grain to be moved) — Qd = sed. load, $d50$ = bed surface grain size

Sinuosity = $\frac{L_c}{L_v}$ channel length / valley length (from meandering to braided)

Q = discharge, S = slope

T_{c^*} = dimensionless critical shear stress

Channel Response $Q_p d50 = Q_s$

Recurrance Interval = how likely that flood would occur in any given year. $R.I. = \frac{(n+1)}{m} = \frac{(\#\text{ of records} + 1)}{\text{rank}}$ is in years

Reynolds # $R_e = \frac{\overline{v} \cdot D}{\nu}$ $\nu = \frac{\mu}{\rho_f}$ $R_e < 2000$ = laminar

$R_e > 4000$ = turbulent

* Resistance to motion depends on size, shape, density on grain particles

Perennial streams – Streams all year long. Ephemeral Streams – turns streams after runoff, or snowmelt

Semi-Ephemeral stream – parts of the year the stream has water.

Landslides

SS = Shear strength, C = cohesion, σ' = effective stress, ϕ = angle of internal friction, $\sigma' = \sigma - P_w$

Colluvium – unsorted mobile/potentially mobile gravity driven deposits on hillsides

Shear Strength – angle of internal friction

Effective Normal stress – bulk density & gravitational acceleration

$SS = C + \sigma' \tan\phi$

hillslope: convex, straight, concave (no'd evolved)

Fall – as it sounds

Debris flow – like a dirt stream on hillside

Slip – like a stair creeper shifting/falling

Occurs by	Triggers	Physical weathering
① Angle of repose exceeded	lots rains,	Thermal expansion/contraction – from sunlight based on position
② pore water pressure	Quakes,	Frost wedging – expand & contract water
③ Shear strength of material decreased	Volcanoes,	Salt crystal growth – (arid/ran) water solution "honeycomb weathering"
④ bedding & fracture orientation	oversteepening, modified slope.	pressure release – on fault
		Biological – root wedging, burrowing

Erosion is moving soil (sed, rock) by wind/water (fluid)

Chemical weathering

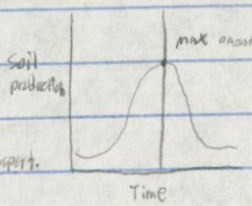
Dissolution – dissolve water w/ CO2 in it

Hydrolysis – water in sed. pores alters form

Oxydation – rusting

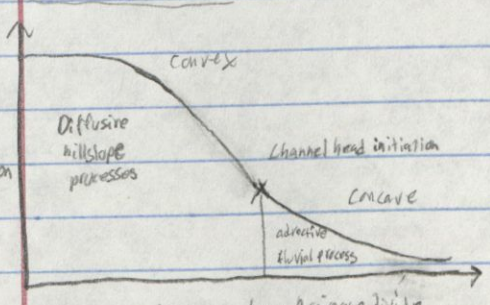
Biological – Lichen on rocks add acid to break rocks

Soil production – formation of soil from bedrock as a function of overlying soil thickness



needs some starting soil (regolith) to accumulate.

Transport limited slopes (humid-temperate regions) no soil production than downslope transport.



Diffusive Transport – slow gravity driven $q_s = -k \frac{\text{diffusive transport}}{\text{slope}}$ Convex

Advective Transport – physical transport of material by fluid ie: landslide, or water.

Glaciers

accumulation > ablation = move Glacier

Glaciers - moving (abrading) accumulation & deformation of snow & ice Plastic deformation

dividing line. Zones
accumulation - (snowing) cold enough
ablation - (melting) warm enough

Forms
1. Snowfalls
2. accumulates/compresses
3. Snow recrystalize to Ice

Ice sheet (continental Glaciers) Antartica, Greenland

Ice Feilds → But smaller Icesheet Surface Area

(rivers do V shaped) Valley Glaciers gouges U shape valley

Peidmont Glacier

Hanging Glacier - around Cirques dropping over Mts

Cirque Glacier

Ice Cap - Greenland - covers topography (Ice a non-attached ice sheet in Mts)

Tarn - Small Mnt. Lake (usually from old Cirques)

Calving - Icebergs form from breaking off

Arete - Mnt btw 2 Glaciers (very steep)

Horn - Mnt btw 3 Glaciers (very sharp)

Glacial Outwash - delta, braided stream

Terminal Moraine - furthest down valley. Used to date glaciers

Recessional Moraine - deposits left as Glacier retreated

Esker - stream deposits in bottom

Drumlins - depositional mounds, show direction of travel

Rouch Moutonnee - erosional, Glacier moves bedrock has. rocks.

Medial Morraine - Paralell morraine along center of Glacier

Lateral Morraine - Paralell alongside Glacier

Glacial scouring @ bottom but rotates upward.

Dating

- Sediment/ice cores show ^{18}O levels
- Pollen

1.2 ma ago Pleisticene

Colder water = mo' ^{18}O in foram shells

Cause Glaciation
- Milankovitch cycles - earth's tilt & orbit Δ
- Enccentricity (revolutions around sun)
- Volcanoes - release plumb
- Thermohaline Climate - (Seas Ctrl. Temp)

- mechanism or mound / material, sed.

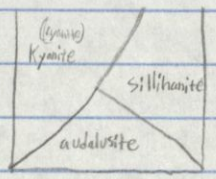
Mineralogy

S = 2^+ or 6^+

Minerals – naturally occuring crystalline solid, with definate but not always fixed chem. composition

1822 MOHS scale of hardness (talc - diamond) (1, 5 (scratch glass) 10 diamond)

1828 polarizing microscope 1912 x-ray defraction 1960 electron microprobe



Seismology – speed of seismic waves passing through earth gives rough density, composition of earth

In Earth	In Crust
Fe ~35%	O ~ 45%
O ~ 30%	Si ~ 28%
Si ~ 15%	Al ~ 8%
Mg ~ 13%	

Common minerals in Crust
1. Plagioclase feldspar
2. K-spar
3. Quartz

Goldschmidt (father of geochem) made 4 categories of minerals from studying ① meteorites ② smelting products & slags (sulfides, silicates) ③ natural rocks

Siderophile – (no'metallic) Fe, Co, Ni Chalcophile (likes to bond w/ sulfur) Cu, Ag, Au Lithophile (likes to bond w/ silica) Li, Na, K Atmophile (in atmosphere) He, Ne, O, H, N

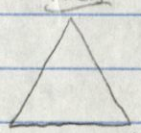
classify by chem.

During 18th C. hist. of mineralogy developing w/ chem/physics. thought it was by ① crystal form (Linnaeus, Hauy) ② chem/physical prop (Werner)

19th C – Berzelius 1814 back: republished in 1850; 3rd ed. Dana's systems of mineralogy ① chem compo ② structure & other props.

$^{238}U \xrightarrow{\text{decay}} {}^{206}Pb$ $^{235}U \rightarrow {}^{207}Pb$

Ionic Bonding



Van der Waals bonding – (weak) no e^- share/transfers
Polarization of atoms like magnets.
Ex: graphite sheets

Nanometers	Angstrom
Size of Atoms 10^{-9} nm	or 10^{-10} Å

Covalent bonding

cations radius / anions radius (for individual atoms)

Coordination – # of nearest neighbors (ions in contact)

① size limits # of ions ③ overall polyhedron shape-forms ex: NaCl CN = 6 Cl/6 Na's
② arrange around central ion ④ # of anions in polyhedron = coordination # of the cation.

$\frac{R_c}{R_A}$ = Radius Ratio

$D_{(C-A)} = \frac{(\Sigma R + CN)}{(R_c/R_A)}$

Close packing of spheres – ex: closest packing of oranges possible. the small gaps are Interstitial space

R_c/R_A	C.N.	Type
1	12	Hexagonal (closest packing)
1 – 0.732	8	Cubic
0.732 – 0.414	6	Octahedral
0.414 – 0.225	4	Tetrahedral
0.225 – 0.155	3	Triangular
< 0.155	2	Linear

② Paulings Rules

(electrostatic valency) bond strength = Charge (cation) / C.N. ex: [6] Al b.s. = 3/6 = 1/2

for neighboring Anions & Cations across mineral is the same everywhere.

Isodesmic – b.s. for e/ cation & anion = the same ex: halite b.s. = 1 from Cat. to an. & vice versa

Anisodesmic – b.s. is dif. for e/ cation & anion calcite $\frac{2}{6}$ $\frac{4}{8}$ $\frac{3}{6}$ $\frac{1}{2}$ dif bond strengths no same

Mesodesmic – b.s. is exactly ½ of anion (valence) charge. explains why silica tetrahedral link together
SiO_2 b.s. = 2 charge of Si = 4 $\frac{4}{2} = 2$

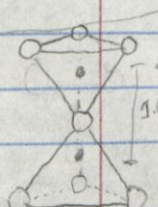
③ Shared edges especially faces decrease stability

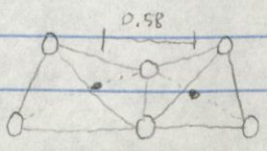
④ In crystalline structures w/ several cations the High valency & small C.N. tend to not share polyhedral elements

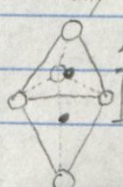
⑤ Parsimony – the # of dif. crystals tend to be small.

① R_c/R_A determines Coordination polyhedron

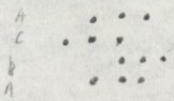
ABAB... Hexagonal closest packing
ABCA... Cubic closest packing

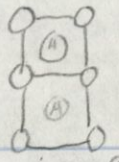






Cubic closest packing

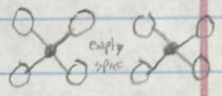




Front view
simple cubic

Cation / anion

Front view



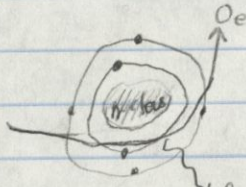
Ionic structure types — AX structure — Halite [6] $NaCl$ – cubic central packing of Cl. Na in octahedral sites

AX_2 Fluorite CaF_2 – Simple cubic packing Ca in every other cupic

A_2X_3 Al_2O_3, Fe_2O_3

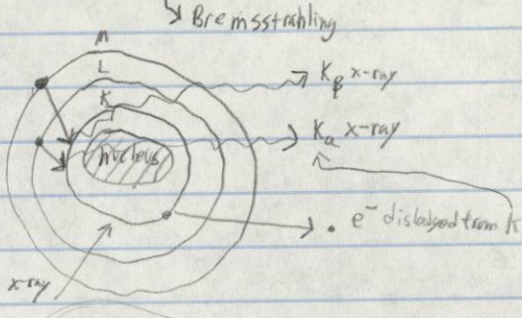
1895 Wilhelm Conrad Roentgen discovered x-rays = 10^{-10} or Å

$E = hc/\lambda$

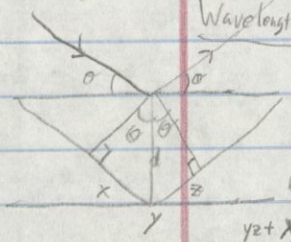


Bremsstrahling = breaking radiation of

(Background noise)



Wavelength Characteristics = noticible peaks of x-rays



Planes of atoms in mineral

$yz + xy = n \cdot \lambda = 2d\sin\theta$ Bragg equation

or $d = \frac{\lambda}{2\sin\theta}$

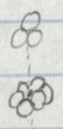
$\lambda = 1.5604$ Å

Isostructural requirements — ① same relative size of anions & cations ② Similar formulas

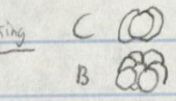
ex: $NaCl$ & PbS ; $CaCO_3$ & $FeCO_3$

Polymorphism – Same formula, diff structure. Calcite & aragonite; graphite & diamond.

Hexagonal Closest Packing — 12 CN — ABAB...



Cubic Closest Packing



Simple Closest Packing

Polymorphisms

① Reconstructive Transformations — break bonds (needs alot of energy usually T [meteorite impact]) not very reversable, sluggish ex: graphite to diamond

② Displacive Transformation — no bonds breaking, only simple kinking (less energy) ex: low & high grade Quartz coesite to stishovite

③ Order-disorder Transformations — ex: ABA / BAB / ABB (high T, cooling quick, mo' disordered) V. AAA / BBB / AAA (low T, cool slow, mo' ordered)

Solid solutions — specific atomic sites could have element substitutions
① Simple — ions have same charge ex $Mg^{2+} = Fe^{2+}$; K = Na
② Coupled — mult. ions w/ in net. same charge ex: NaSi = CaAl
③ Vacancy — empty site in mineral maybe filled (partially) if needed the charge

Crystals Form

① melts (magma) cooling rates determin nucleation.
② Vapors (Tridymite, christobalite, K-spar) high Temp. Low pres. SiO_2
② Aqueous Solutions (evaporates, geodes, hydrothermal fluids (hot pots) mainly sulfides
④ Solid state (metamorphic) calcite & aragonite Δ its shape

Crystal Defects

① Various (could also be miss aligned matrix) Schottky — 1 cation & 1 anion vacancy Frenkel — a cation shifted its position to interstitial area.

② Defects ctrl diffusion — Δs in physical & chem environments. Δs color & mineral deformation (how minerals respond to stress

③ Zoning — diff. colors & shades rep. dif. chem compositions ex: corundum has Cr for rubies Si & Al for saphires
(tourmaline = watermelon pink-green)

④ Twinning — symmetrical intergrowth of 2 or more crystals of same mineral, occurs as crystals grow; polymorphic transformation; deformation.

⑤ Exsolution — mineral striations overtop of a background mineral medium (Δ chem. compo) K-spar lines lamella over plagioclase. (plutonic rocks allow minerals cool to seperate striations)

⑥ Pseudomorphism — mineral w/ outward crystal from another mineral ex: petrafied wood.

$An = \text{anorthite } \frac{Ca}{(Ca+Na+K)} \cdot 100\%$ / $Ab = \text{albite } \frac{Na}{(Ca+Na+K)} \cdot 100\%$ / $Or = \text{orthoclase } \frac{K}{(Ca+Na+K)} \cdot 100\%$

Symmetry

(balanced proportioned)
miller plane or rotation (center of axis)

2 fold symmetry 180° / 3-fold symmetry / 4 fold / 6 fold

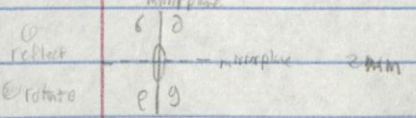
Rotation no Δ handedness of rotation / Reflection Δs handedness / Inversion Δs handedness / Rotoinversion — no Δ in handedness

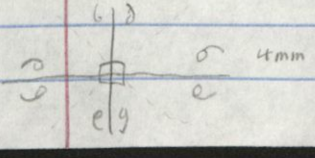
Johann Hessel (1830) only 32 possible element combo's (X, Y, Z) Space groups 2 bar
m = $\bar{2}$
$\bar{1}$ = i

10 basic symmetry 1, 2, 3, 4, 6, m = mirror plane, i = central symmetry, $\bar{1}, \bar{2}, \bar{3}, \bar{4}, \bar{6}$ 2/m = 2 over m

Paramagnetic = Could be magnetic if w/ a current Ferrimagnetic = always be magnetic (magnetite)
Diamagnetic = minerals will never be magnetic

2mm = "2, m, m" 2 fold axis w/ 2 mirror planes in the same place as fold





Crystal Systems
Triclinic a, b, c ; needs α β γ
Monoclinic a, b, c ; β
Orthorhombic a, b, c
Trigonal / Hexagonal a, c (Rhombohedral) needs γ
Isometric a

Crystallographic axis — use external form described by rot. axes to estimate center

Tetragonal a, c

ex: | I | 4/m | 3/2 | a |

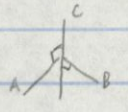
body centered	4 fold w/perp. mirror	3 fold screw axis	glide plane on a

reference angles to plane

Miller Indecies

Unit cell - smallest unit of a structure that is infinately repeatable to make a whole structure

Face Intercepts - parallel to 2 axes & intercept 3rd



series of whole #s from intercepts by their inversions, followed by clearing of fractions

0 = no intercepts. (Hexagonal has 4 planes $a_1 | a_2 | a_3 | c$)

ex: 3 1 ∞

① Invert $\frac{1}{3}\ \frac{1}{1}\ \frac{1}{\infty} \times 3 = 130$

② clear fractions (by highest denominator)

$$\frac{\text{Face x}}{\text{Unit Face x}} = \frac{1}{\text{answer}} \left(\frac{\text{highest denominator}}{1}\right) \approx \text{Whole \#}$$

Bravais Lattice

I = body centered: nodes @ corners + in center

P = Primitive: nodes @ corners

F = Face centered: nodes @ c/corner & c/face

R = Rhombohedral (primitive tilted)

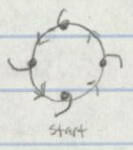
C = nodes @ c/corner & body & 2 faces (c-axis)

Translation = • ⟶ • ⟶ •

a = on a axis n or d = diagonal glideplane,

Glideplane = x x / x x ⟶ (reflection + translation) (like walking alt. feet)

Screw axis = (rotation + translation)



2_1 = 2fold screw axis

Unit cell's can be calculated: $Z = \frac{(D)(N)(\text{Vol.})}{MW}$

D = density, N = avogadro's # [6.023 x 10^{23}]

Vol = volume of cell, MW = formula weight of mineral

Basalt from melt. mantle — Granite from melt. crust

Grainsize: fine grain = volcanic (chem analysis) — med-coarse = plutonic (point counting)

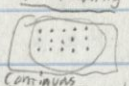
Igneous rocks - Quartz (12%), Plagioclase (39%), K-spar (12%)

65% 27% 8%

In Crust: Igneous, metamorphic, Sedimentary

Basalt magma 1200°–1000°C (high) mafic → Discontinuous → Granite 900°–700°C (low) felsic → (quartz)

Point counting



thin section I.D. minerals/spots to get mineral %

Continuous → Ca rich plag. → Na rich plag. (cooling)

Silicates

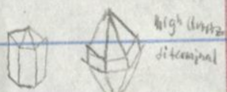
Nesosilicates – isolated Si-tetrahedral | Sorosilicates – Si_2O_7 group (bowties) | Cyclosilicates – Ring of Tetrahedra (Si_6O_{18}) common one

Inosilicates – chains of tetrahedra (single or double) | phyllosilicates – sheets of tetrahedra (micas) | Tectosilicates – framework of tetrahedra

Quartz — high: 6-fold screw axis; low: 3-fold screw axis

colors

Low Quartz



Phenocryst – well devo. crystals in matrix

Porphyritic – small crystals in fine grained matrix

Pegmatitic – huge crystals in rock sized of pebbles

Rose Quartz = color from dumortierite fibers

smoky = radiation damage or Al sub. Si

amethyst = slight Fe^{3+} impurity

Blue = ilmenite nanofibers

Citrine = hematite nanofibers

White/milky = microscopic fluids entrapped.

microcrystalline varieties SiO_2

1. Chalcedony (fiberous) banded form (asbestos) aqueous solution
2. Chert + flint
3. Jasper (red from hematite impurity)
4. Tiger's eye replacement of asbestos (pseudomorph)

Opal mineraloid (water in btw pores)

Lechatelierite – silica glasses

from lightening strikes

	Igneous	Sed.	Meta
Felsic:	Granite, Rhyolite	Sandstone,	Quartzite

fine matrix

$SiO_2 + C \rightarrow Si + CO_2$

Feldspar

	clays
disordered ↕ sanidine	– monoclinic
Ortnoclase	– monoclinic
Ordered microcline	– Triclinic

Albite : An_{0-10}
Anorthite : An_{90-100}

perthite host is the matrix

mesoperthite ½ host; ½ lamellae

antiperthite lamellae is matrix

Quartz $\frac{Si}{Si+Na} = 1$

Albite ($NaAlSi_3O_8$) $\frac{Si}{Si+Na} = \frac{3}{4}$

nephelene ($NaAlSiO_4$) $\frac{Si}{Si+Na} = \frac{1}{2}$

Mg — Ne (in same rock) — Ab — Qtz (in same rock)
0 — .5 — .75 — 1

zeolites – framework silicates in water take of cage shape

Feldspathoids – stuffed derivative of tridimite

Albite An_{0-10} and Na | Oligoclase An_{10-30} | Andesine An_{30-50} | Labradorite An_{50-70} | Bytownite An_{70-90} | Anorthite An_{90-100}

Amphibole

2 chains, usually dark & monoclinic hornblende (120° & 60° cleavage planes)

$^{[6-12]}A\ ^{[6-8]}Ca_2\ ^{[6]}Mg_5\ ^{[4]}Si_8O_{22}(OH)_2$ more

wide (most) Double chains

[all Mg to all Fe] Form

Tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$ to $Ca_2Fe_5Si_8O_{22}(OH)_2$

Ferroactinolite

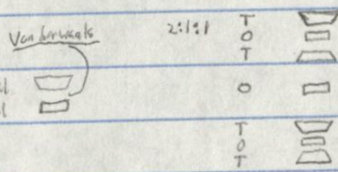
Grunerite = all Fe

Van der waals

1:1 layer silicates T tetrahedral, O octahedral

2:1 layer silicates T O T

2:1:1 T O T O T O T



sheet silicates
Biotite & muscovite

in center

Trioctahedral – Mg^{2+} or Fe^{2+} all 3 sites occupied

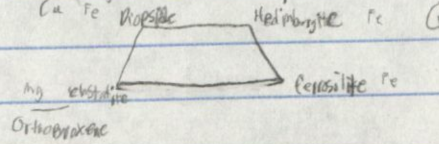
Dioctahedral – Al^{3+} only 2 sides filled.

K is in ½ bondstrength w/ oxygens = Cleavage breaks

Pyroxenes

Single chain no (OH)s octahedral m_1, m_2 could be ordered or disordered cubic site. Cleavage @ ≈90°, glideplane

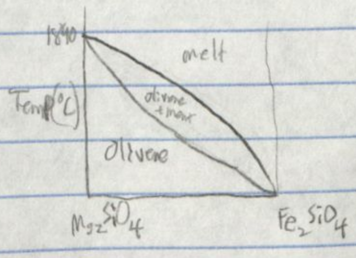
Quadrilateral



Olivene

nesosilicates

Silica tetrahedra not linked together



MgO — Fo (.33) — En (.5) — SiO_2

$\frac{Si}{Si+Mg}$

Mg & Fe swap w/e/o

Olivine & Quartz don't go together

mantle mineralogy

melt by dec. pressure

usually cross. peridotite layer

peridotite = olivine & pyroxene

lherzolite = olivine + opx + cpx

harzburgic = olivine + opx

Ring Silicates (cyclosilicates) Si:O usually 1:3

Beryl $^{[4]}Be_3{}^{[6]}Al_2Si_6O_{18}$ Hexagonal felsic Granite, peg

Tourmaline $(Na,Ca)(Li,Mg,Al)_3(Al,Fe,Mn)_6(BO_3)_3(Si_6O_{18})(OH)_4$ hexagonal

---

Sedimentary Rocks 7.9% in Earth's crust

Limestone 10%
Sandstone 15%
Shale 70%

Shales - clay, quartz

Sandstone - Quartz, possible feldspar
① Started as siliceous oozes.

Chert microcrystalline of SiO_2 ② Nodular replacement in shallow water. Silica dissolution, migration, reprecipitation

Shales - fissile (Breaks into flakes)

clay = Sed. particles less than 0.0002 mm

clay sized = particles dimensions less than 0.0002 mm

Clay minerals = sheet silicate minerals in soil seds.

Smectite Could expand or shrink (montmorillenite)

Vermiculite ← ultramafic when heated can absorb lots of water

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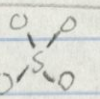
Others 5% of surface

Sulfates loose $6e^-$ to be 6^+ cation SO_4 group



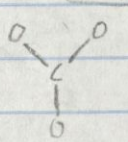
$\frac{6}{4} = 3/2$ b.s.

evaporates Chlorides, Sulfates (gypsum), Carbonates

Gypsum
- satin spar - fibrous
- Alabaster - fine grain stone
- Selenite - clear crystals

~70°C = plaster of paris
>100°C = Anhydrite

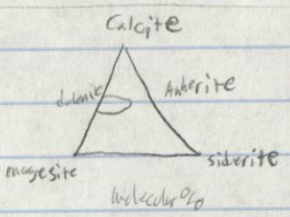
Carbonates Limestone 10% in surface. Converted to lime (CaO) = heated up



Charge = 4/2 b.s. Ca = 2/6 b.s.

C.N.

Rhombohedral



Dolostone in time

Precambrian 80:1
Paleozoic 3:1
Younger 1:3 – had better conditions to create it, or older limestone converted to dolostone by fluid vents.

Possible ways to produce dolostone

① $Ca + Mg + 2(CO_3) \rightarrow CaMg(CO_3)_2$ precipitate from sea water

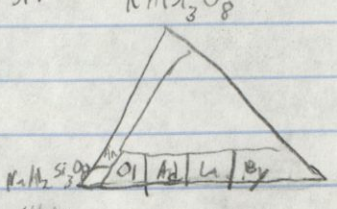
② $Mg + 2(CaCO_3) \leftarrow CaMg(CO_3)_2$ substitute mg for a Ca.

③ $CaCO_3 + Mg + (CO_3)_2 = CaMg(CO_3)_2$ fluid supplies both mg & carbonates

Aragonite polymorph of $CaCO_3$ - orthorhombic Pseudo hexagonal

Twinning of 3 in hot springs or low P. environment.

K-spar $KAlSi_3O_8$



Metamorphic Rocks

mineralogical or textural Δ in T & P

shales: clays → micas

Initial equilibrium state —metamorphic→ new eq. state

Lithification → Diagenesis —150–200°C→ metamorphism —650°+→ melt

chlorite or epidote in mafic rocks, muscovite in shale

metamorphic zones due Δ in temp

Index minerals
- Biotite – 400°C
- Garnet – 450°C
- staurolite – 500°C
- kyanite – 550°C
- Sillimanite – 600°C

① dif. rocks w/ same meta. could have dif. minerals
② minerals in meta. ≠ dif. starting materials

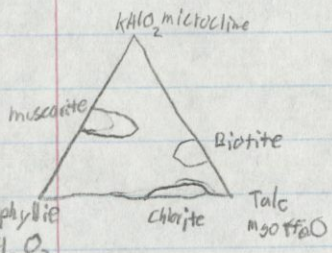
Green schist, amphibole, Granulite, Blue schist } meta. basalt

Asbestos is a habit (fiberous) not a specific mineral.

harmful if inhaled

Chrysotile – harmful form

Chrysotile – not very harmful, 90% used in commercial buildings.

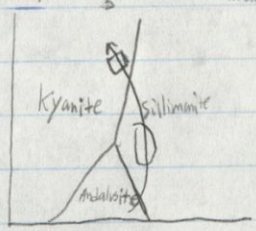


Aluminum Silicates

[5]Al [6]Al SiO_5 Kyanite (Triclinic)

[6]Al [5]Al SiO_5 Andalusite (orthorombic)

[6]Al [4]Al SiO_5 Sillimanite



staurolite usually twins

□ muscovite, quartz → k-spar, ky, H_2O

○ muscovite, qtz → k-spar, sil, H_2O

Garnet

mesosilicates usually isometric, red/pink

A_3^{2+} cubic (dipyramid) B_2^{3+} (octahedral) Si_3O_{12}

pyralspite
- $Mg_3Al_2Si_3O_{12}$ Pyrope
- $Fe_3Al_2Si_3O_{12}$ Almandine
- $Mn_3Al_2Si_3O_{12}$ Spessartine

ugrandite
- $Ca_3Al_2Si_3O_{12}$ Grossular
- $Ca_3Fe^{3+}Si_3O_{12}$ Andradite
- $Ca_3Cr_2Si_3O_{12}$ Uvarovite

P & T ↓
1. Chlorite
2. biotite
3. Garnet
4. staurolite
5. kyanite
6. sillimanite
7. 2nd sillimanite zone

amphibolites = hornblende + plag ± garnet

Granulite – ortho pyroxenes, clinopyroxenes, plag ± garnet

pyralspite – pyrope, almandine, spectarine (combo)

Clino = monoclinic (hint)

Epidote – bowtie (Si_2O_7) monoclinic

Ore

– mineral deposits w/ sufficient concentration to make it profitable to mine

Ore deposits

Geol + Eco + Pol.

Cu in Chalcopyrite

Cu	63.546	2/3 34.63
Fe	55.847	30.43
S	2 (32.00)	34.94

$\frac{\text{Ave. abundance in rock (wt.\%)}}{\text{Ave. min. ecotrade (\%)}}$ = concentration of ore

$14 \cdot (0.34\,63) = 4.85$ kg Cu per 1000 kg rock 0.485% Cu

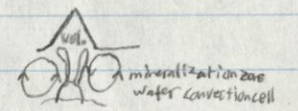
$\frac{4.85}{1000} = X \cdot 100$ ≈

Concentrate minerals

(1) Magmatic Processes

- Crystal Settling (density) ex: magma cools, heavy minerals settle down
- disseminated - porphyritic or phenocryst have important minerals
- Late Magmatic - pegmatites of elements that no transfer into micas, hornblende, qtz, b/c Late Crystallization
- Skarns (metasomatic) - chem. d by fluids from cooled magma intrusions melts. magmatic water transports ions to bedded zones

(2) Hydrothermal - veins, porphyries, blacksmokers) from volcanoes or Subduction Zones



(3) Sed. Processes

- evaporation ex: gypsum, salt
- placers (wave action to concentrate heavy mineral sets. in body of water)

(4) Weathering residual concentration Same and susceptible to weathering (hematite - laterite)

- Bauxite (Al ore) Tropical climates → weathers off soluble stuff leaves behind insoluble stuff

Hydroxides

Minerals Final Exam

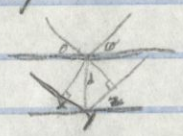
Gold schmidt — 4 groups of minerals: Lithophile (Si, O bonds), Chalcophile (likes S bonds), Siderophile (likes Fe bonds), Atmophile (in atmosphere bonds)

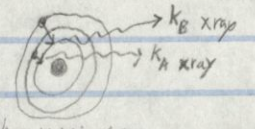
figured it out from observing: meteorites, smelting products & slag waste, natural observations

C.N. = # of anions in mineral. , Radius Ratio = $\frac{R_{cation}}{R_{anion}}$, B.S. = $\frac{cation\ charge}{C.N.}$

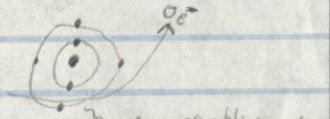
Isodesmic - b.s. for e/ cation the same, Mesodesmic - b.s. is ½ of anion valence charge, Anisodesmic - b.s. is dif. for e/ cation

$y_z + x_y = n\lambda = 2d \sin\theta$ Bragg Equation





Characteristic x-ray



Bremsstrahling x-ray

Hexagonal Closest packing : AB... Cubic closest packing ABC...

Reconstructive Transformations (Calcite → diamond / Polymorphism) break bonds, Heat added Energy., Displacive Transformation - kink bonds ie easiest, Disordered Order-disorder Transformations - slow cooling of ordered

Defects

Zoning: ex: Tourmaline dif. chem compositions (Ca) Twinning - 2 crystals grow (same) Exsolution - mineral striations w/ underlying mineral medium

An = anorthite $\frac{Ca}{Ca+Na+K} \cdot 100\%$ / Ab = Albite $\frac{Na}{Ca+Na+K}$ / Or = Orthoclase $\frac{K}{Ca+Na+K}$

Crystal systems (# axes)

Triclinic	a,b,c ; αβγ	
Monoclinic	a,b,c ; β	
Orthorhombic	a, b, c	
Trigonal / Rhombohedral / Hexagonal (4 axes Y)	a, c	
Tetragonal	a, c	
Isometric	a	

Miller Indecies - unitcell smallest, intimately repeatable unit of a structure.

ex: 3 1 ∞

① invert $\frac{1}{3}\ \frac{1}{1}\ \frac{1}{\infty}$ ×3 = 1 3 0

② clear fractions (highest denominator)

$\frac{\text{Face X}}{\text{unit face X}} = \frac{1}{\text{answer}}$ (highest denominator / 1) = whole #

unit cell calculation: $Z \approx \frac{D(N)(Vol.)}{MW}$ D = density, N = Avogadro's # (6.023×10^{23}), vol. = volume, MW = formula weight

I = body centered nodes @ corners & center,

P = primitive nodes @ corners, R = Rhombohedral Primitive tilted

F = Face Centered nodes @ corners & @ centers of faces, (= nodes @ ⅛ of corner & ½ faces (E-W axis)

Bowens Rxn Series

Mafic

Felsic

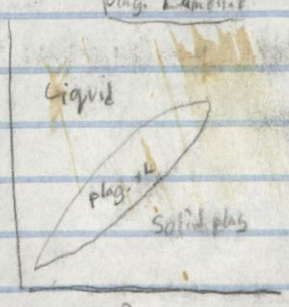
1200°C Olivine → Pyroxene → Amphibole → 900°C Biotite → Orthoclase → Muscovite → Quartz → 700°C

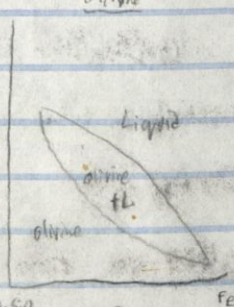
Ca plag Anorthite

Na plag Albite

I 4/m 3₂ a

body centered, four fold w/ perpendicular mirror, 3 fold screw axis, glide plane on a





Igneous

3fold screwaxis Low Qtz — 6fold screwaxis High Qtz

Tectosilicates — Framework tetrahedron

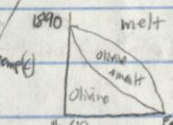
Opal = mineraloid water bearing pores

Microcrystalline varieties of SiO_2: chert, chalcedony (fibrous subspecies of Qtz), Jasper, ↑

Plagioclase — Albite (Na) An_{0-10}, oligoclase An_{10-30}, Andesine An_{30-50}, Labradorite An_{50-70}, Bytownite An_{70-90}, Anorthite (Ca) An_{90-100}

perthite – host in matrix — **mesoperthite** – ½ host, ½ lamellae — **antiperthite** – Lamellae of K-spar

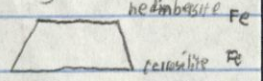
Olivine — Qtz & Ol2 no so together



Inosilicates — chains of tetrahedra (single/double) — **Amphiboles** 2 chains, dark & prismatic (hornblende) — 120° & 60° cleavage

$(Na,K)_{0-1}[A]^{2-3}Ca_2[B]Mg_5[T]Si_8O_{22}(OH)_2$ — **Tremolite** $Ca_2Mg_5Si_8O_{22}(OH)_2$ to $Ca_2Fe_5Si_8O_{22}(OH)_2$ (all Mg to all Fe)

Pyroxenes — 1 chain, no (OH)s, octahedral m_1, m_2 ordered or disordered cubic. Cleavage = 90°



Phyllosilicates — sheets of tetrahedra (micas) — 1:1 T Tetrahedral, O octahedral, Van der waals — 2:1 T O T — 2:1:1 T O T O T

Trioctahedral – Mg or Fe (Biotite)

Dioctahedral – Al^{3+} (Muscarine)

K has ½ b/t = Cleavage prior

Cyclosilicates — ring of tetrahedra (common Si_6O_{18}) — **Beryl** hexagonal felsic granite. — **Tourmaline** (D) hexagonal

Sedimentary

Shales – clay & Qtz — **Sandstone** – Qtz, maybe Feldspar • started as siliceous oozes, • nodular replacement in shallow water reprecipitation

Shales – fiscile, sheet silicates — Smectite/vermiculite/montmorillonite – could expand or shrink w/ water getting in the pores

evaporites – chlorides, (Gypsum) Sulfides, Carbonates — **Gypsum** — Satinspar – fibrous, Alabaster – stone, Selenite – clear crystals, — **Sulfates** – loose $6e^-$ to be 6+ cation SO_4

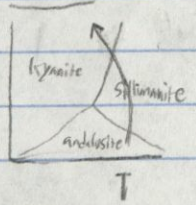
Carbonates – limestone 10% in surface convert to lime when CaO when heated up. aragonite — 3 twinning / mo de lost one fracture

Metamorphic

Index minerals — Metamorphic zones — eskola

① Chlorite ~250°C — rocket @ basalt
② Biotite ~400°C
③ Garnet ~450°C
④ Staurolite ~500°C
⑤ kyanite ~550°C
⑥ Sillimanite ~600°C

Asbestos – fibrous habit not a mineral. — **chrocidolite** – harmful form — **Chrysotile** – not very harmful, 90% in Commercial building

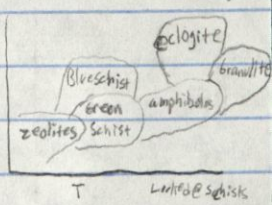


amphibolites – hornblende + plag ± garnet

Granulite – orthopyroxenes, clinopyroxenes, plag. ± garnet

Pyralspite – Pyrope, almandine, spessartine (mnga)

Garnet – nesosilicate



Geol. + Eco. + Pol.

Ore – mineral deposit w/ sufficient concentration to make it profitable to mine

Ave. abundance in Rock (wt.%) / Ave. min. eco. grade (%) = ore concentration

Cu in Chalcopyrite

Cu	63.546	34.63 %
Fe	55.84 ?	30.43 %
S	2(32.00)	34.94 %

14 · (0.34635) = 4.85 kg Cu per 1000 kg rock 0.485% Cu

14 kg Cu per 1000 kg rock — $\frac{4.85}{1000} = x \cdot 100\%$

Concentrate minerals

① Magmatic processes — Crystal settling (density), disseminated, late to magmatism – Xs, Skarns chem Δ by fluids transport ions to baked zones — no Al micas or Qtz

② Hydrothermal — veins, porphyries, blanket deposits (volcanoes & subduction zones)

③ Sed. Processes — evaporites (Gypsum, Salt), Placers (wave action & concentrates heavy minerals)

④ Weathering — some minerals soluble to extreme weathering (tropical climate) ex: Bauxite (Al ore) Tropical climates weathers OH soluble stuff leaves behind insoluble stuff.

Sean Franco

Hydrology

Sig figs mult/divide = least # add/subtract = least # of decimals.

2/3 of precipitation goes back to atmosphere b/c plants.

$\frac{\Delta \text{substance}}{\Delta \text{time}} = q_{in} + q_{out}$ $\frac{\Delta S}{\Delta t} \neq 0$ = transient system (net water leave/enter) $\frac{\Delta S}{\Delta t} = 0$ = equilibrium system

Residence Time = how long a substance lingers in a reservoir $T_r = \frac{\text{total quantity (could be V)}}{\text{(all inputs) or (all outputs)}}$

Precipitation

atmosphere water + vapor pressure

relative humidity = $\frac{\text{vapor pressure}}{\text{saturation vapor pressure}} \times 100 = \%$

dew point – temp. to cool down to to reach 100% humidity to create condensation. @ 100% Saturation it = air temp

Ideal gas law = $\frac{P}{T_a \rho_a} = R$ P = bar pressure ρ_a = airmass density. T_a = air temp R = gas constant

adiabatic Δ in temp = no loss/gain of energy **Environmental Lapse Rate** = temp. dec. higher in atmosphere $\frac{-7°C}{1000m}$

dry adiabatic lapse rate = air is unsaturated during rise: $10°C/km$

wet adiabatic lapse rate = air is saturated during rise: $5°C/km$

Ingredients for precipitation I

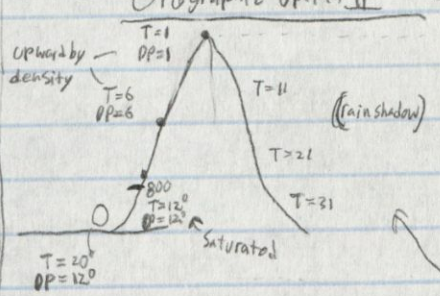
1. **cool air to dewpoint**: adiabatic cooling b/c uplift
   uplift by convective, orographic, cyclone processes.
2. **Nuclei center**: $>10^{-4}$ size, smoke/dust microparticles
   uplifted air holds them up.
3. **Droplet growth**: (0.4–4mm) density to be heavier than
   uplift push to let it fall.
4. **Convergence of water vapor**: clouds from all around
   b/c $10\ km^3$ cloud = 1cm rain.

Generating Uplift I (convection)

Ground heats up + air heat uplifts in convection cells = intense precipitation

– cloud base b/c of E.L.R. ∴ not big enough particles to rain to reach saturation

Orographic uplift II



clouds move upward to pass mate

elevation (m)	Temp (C)
3000m	−4°C
2000m	4°C
1000m	12°C
0m	20°C

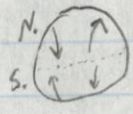
(gets warmer + dryer)

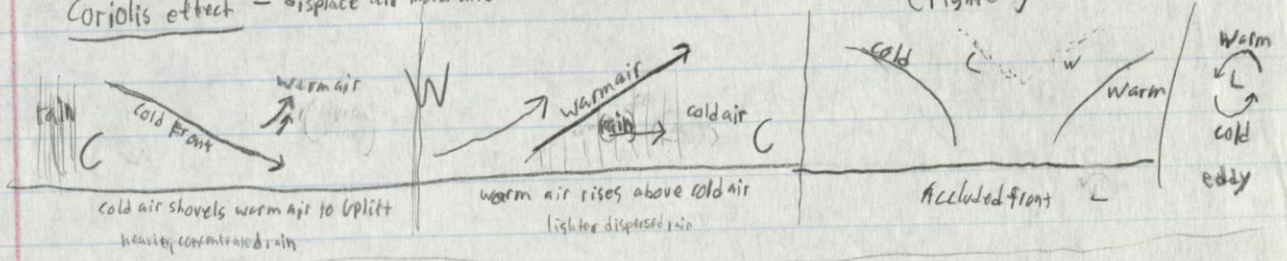
when down the Mnt = less relative humidity = dry adiabatic lapse rate

Atmospheric Circulation uplift III

spins b/c travels faster as away from poles.

Coriolis effect – displace air movements in dif. alt. N. hemisphere counter clockwise. (deflection to right (east)) opposite for Southern Hem.





- __% of __
- more or equal to
- less
- Avg per year.

Sf of rain fall

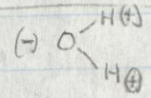
$$Z\text{ score} = \frac{a - \bar{x}}{\sigma}$$ data − mean / Standard deviation

Cumulative (the amount or less) __% chance that a in or less than (equal to or) would be the total amount of rain per year on average.

$T_{return} = \frac{1}{\text{probability}}$ $\frac{1}{Z}$ = on average once every __ yrs a mean rainfall is __ in or less

Complementary cumulative (the amount or more) (find % then 1 − X) __% chance that __ in or more (equal to or) rainfall per year on average.

$T_{return} = \frac{1}{\text{probability}}$ $\frac{1}{\text{new } Z}$ = on average an expected __ in of rain or more in any given year every __ yrs



H-bonds in water make both very high.

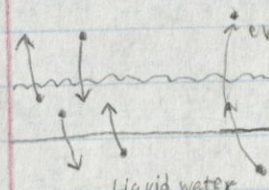
Latent heat = breaks H-bonds but does not Δ overall temp. Water: $\lambda = 2.45 \times 10^6$ J/kg $\frac{\Delta E}{\Delta t}$ to break

specific heat = $c_p = \frac{1}{\text{mass}} = \frac{\Delta E}{\Delta t} = 4200\ J/kg/K$ for water.

net evaporation is diffusive (vapor pressure high → low)

T_a = air temp e_a = air vapor pressure

high T_s and e_s with low e_a to inc. vapor saturated



$\frac{e_a}{e_s} = \frac{\Delta E}{\Delta z}$ wind pushes away saturated air to bring in unsaturated air and cool T_a

no wind = fog

e_a = low temp or dry air low vapor pressure w/ high temps.

- plants re-evaporate 40% of precipitation ei: deforested areas have 40% more precipitation do turn to flooding
- stomata's gather CO_2, let loose H_2O b/c stomata: 100% humidity
  - has to open to get food.
  - m' open e_a has high vapor pressure or high temp $e_s \leq e_a$ open not alot of net loss from stomata, or have to waterlood.
  - m' closed e_a has lower vapor pressure or low temp $e_s > e_a$ closed closed at night, ↓ winter; closed if water loss = death or drought

air is dryer in winter, b/c no stomata's (no leaves)

x < 20 in rain
y > 20 in rain

Evapotranspiration by mass.

Hydrology

Steady flow: $\frac{dv}{dt}$ could = 0 same velocity for the Δ in time. **Uniform flow**: $v\frac{dv}{dx}$ velocity Δ w/ distance (constant in space)

↳ Hydrostatic = water not moving. $\frac{P}{\rho g} = \frac{\rho g h}{\rho g}$ $\frac{\text{pressure}}{(\text{density})(\text{gravity})} = h$ (height above you)

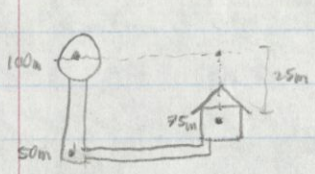
Bernoulli equation $\left(\frac{v^2}{2g} + \frac{P}{\rho_w g} + z\right) = \text{constant}$

measure: velocity + pressure + elevation

unit: L + L + L

Length = energy per unit weight

Assumptions
1. Frictionless
2. steady flow (hydrostatic)
3. low angle substitute tan θ w/ sin θ
4. no Δ in water density



@ 100m = 0', 0', 100' @ 50m = 0', 50', 50' @ 75m = 0', 25', 75'

all adds up to 100m

Mass Transfer of evapotranspiration

$$et = k_e u_a (e_s - e_a)$$

et = evapotranspiration $\left(\frac{\text{Length}}{\text{Time}}\right)$ u_a = wind speed $\left(\frac{m}{s}\right)$ e_a = vapor pressure in @ height z (Pa)

k_e = aerodynamic roughness of surface $\left[\frac{1}{Pa}\right]$ es = vapor pressure @ surface/atmospheric boundary (Pa)

ρ_w = water density $\left(\frac{kg}{m^3}\right)$ ρ_a = air density $\left(\frac{kg}{m^3}\right)$ z_d = displacement height (m)

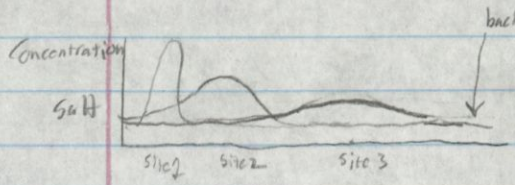
z_0 = surface roughness (m) K = von karman # constant = 0.4

$$k_e = \frac{0.622\rho_a}{P_a \rho_w} \cdot \frac{K^2}{\left(\ln\left[\frac{z_m - z_d}{z_0}\right]\right)^2}$$

On avg. a ____ % chance of ____ ____ or greater least will be a

(Statistical unit ex: averages or medians)

Hydrology Final Exam



Diffusion – decreases the peak and flattens it out

Advection – transports it down stream

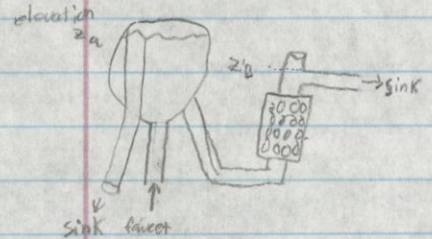
estimated discharge: $Q = \bar{v} d w$ discharge remains constant in a closed system

Continuity allows internal variables to Δ while maintaining a constant discharge

Calculated discharge $Q = \frac{M}{\int_0^t (c_2 - c_1)\,dt} \approx \frac{M}{\sum_{i=1}^{n} (c_2 - c_1)\,dt}$

c_2 = concentration @ certain time

c_1 = background concentration



Porosity – open space in material,

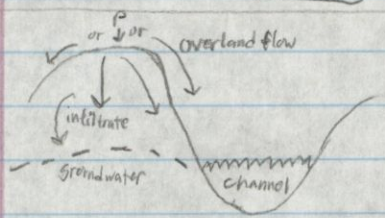
Permiability – connective quality of pores.

Frictional resistant direct w/ velocity

$q = K \frac{\Delta H}{\Delta L}$ K = hydrolic conductivity – ability of porous medium to pass a fluid. properties

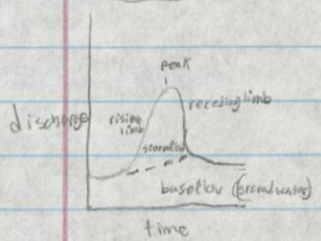
K = slope of specific discharge (q) vs. headgradient (x) w/ y=0 intercept.

$Q = -KA \frac{\Delta H}{\Delta L}$ Dareys Law –



	rate	Speed
instant	① directly precipitates on channel	
cm/s	② overland flow = $P_{(rate)} > I_{(rate)}$	ground is saturated, sand infiltration
subsurface cm/hr	③ Infiltrated = depends on material traveling parallel along Mnt.	
subsurface cm/day	④ Ground water = ~~sub~~subsurface flow	

Hydrograph



mó baseflow b/c it takes long time to infiltrate G.W.

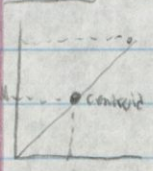
Storm duration – how long storm lasts

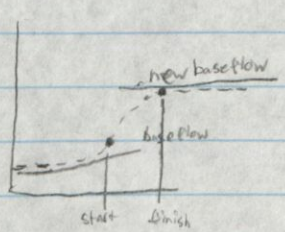
Response lag – difference btw start of stream to start of hyetograph (length dependent on 4 channel types and P(rates) Et & vegitation to overland)

Lag to Peak – time btw start of rain & peak discharge dependent on P(rates), location of P to watershed, surface type, & velocity from slope topography

Time to Rise = long btw start of hydrograph response to peak discharge. length of storm, drainage network, topography

Centroid = median. Lag to Peak = storm location, overland/infiltration, vegetation





$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2} - u\frac{\partial c}{\partial x}$

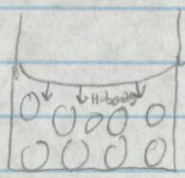
Translation "think advection"

Spredge "think diffusion"

Levee's inc. translation but inc. Q & velocity downstream

exceedance Probability — $P = \frac{r}{n+1}$ (r = rank, n = # of data) Return time — $T = \frac{1}{P}$

Percentiles — how much data falls below them



In Bernoulli equation, there can be neg (-) #s for pressure b/c H-bond capillary action

Capillary Pressure $P_c \propto \frac{1}{r}$ r = radius for pore space. smaller spaces = higher capillary pressure

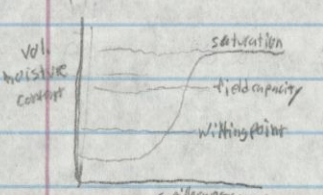
Soil moisture (surpass gravity)

Porosity, n (% open spaces in material) max. amount of water in pores

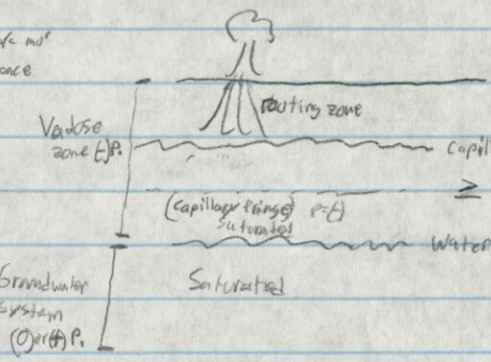
Volumetric water content θ (max $\theta = n$) $= \frac{\text{total V. of water}}{\text{total V. of material}}$

Field Capacity — amount of water in material after gravity ex: saturated non-driping sponge.

Plants & ET suck up water by capillary action Wilting point when vegetation can't take water b/c not strong enough capillary action



Capillary P. gets more neg b/c more pore space drained in/ pore space

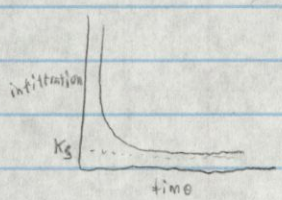


Capillary fringe rises higher in material w/ sml. pore spaces.

Darcy's Law $Q = -KA\frac{\Delta H}{\Delta L}$ Specific discharge $q = -K\frac{\Delta H}{\Delta L}$

Green-Ampt equation $i = q = -K_s\left(\frac{\Psi + Lf}{Lf}\right)$ (i = infiltration rate in subsurface (-))

K_s = material & fluid prop. Saturated K.



K → Hydraulic Conductivity (viscosity & material prop) how fluid passes thru certain medium. Ψ → Capillary pressure (-) from pore space

L_f → time to infiltrate to create saturation. (time for infiltration)

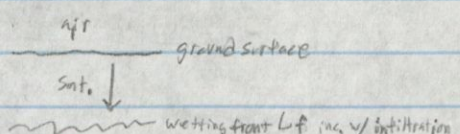
aquifers

aquifide — holds water, but hard to transmit it ex: clay + shales

aquifuge — no hold / no transmit water

Unconfined water table = just dig to hit it

Confined or Artisian w.T. ≈ water table below aquifide



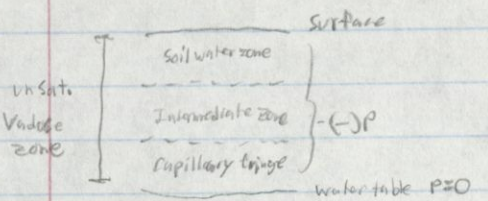
$f_t = f_c + (f_0 - f_c)e^{-kt}$ (f_t = infiltration @ rate t)

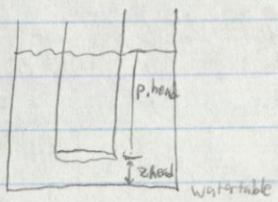
f_c = final infiltration rate

f_0 = initial infiltration

k = material constant

higher Ψ = more infiltration occur





ignore vel. b/c so slowly

make contour lines = $\frac{\text{contour line} - \text{start}}{\text{finish} - \text{start}}$ = ratio to place contour line.

n = porosity

discharge $Q = u \cdot A \left(L^3 \cdot T^{-1}\right)$

$\bar{V} = \frac{Q}{An} = \frac{-K}{n}\left(\frac{dh}{dL}\right)$

Darcy's Law $Q = -K \cdot A \cdot \frac{dh}{dL}$

Q = discharge; K = hydraulic conductivity; A = cross sectional Area; $\frac{dh}{dL}$ = hydrolic gradient

$n = \frac{V_v}{V_t}$ (void / total)

$\frac{Q}{A} = q = -K\left(\frac{dh}{dL}\right)$ specific discharge

aquifer – allow porosity to pass through aquitude – sml. pore spaces prevent water from passing through

unconfined (water table) aquifer – e/ has a bottom (aquitude) less permiable to prevent downward flow

water table – top of unconfined aquifer (can go up or down) top of unconfined all head = =

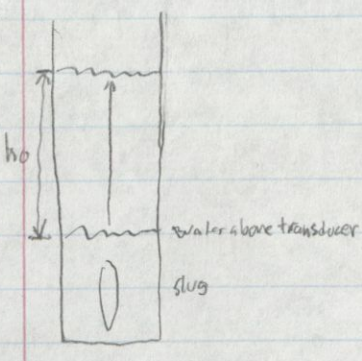
Z head Δ's w/ elevation in aquifer

(independent of e/o)

Confined aquifer – (aquiclude) on top + bottom everywhere (pressure head (ft) > 0) a well will have the water rise above the confining upper layer (no z head) (creates artesian well.) – only has p-head

aquifuge = no permeability, no hydrolic conductivity for water to move through

potentiometric surface – height (z) water would go to if not confined



Pressure (p) = $\rho g h$ to get h

b = aquifer thickness

$\frac{h}{h_o}$

$\frac{Q}{w \cdot b} = q = \frac{Q}{A} = -K\frac{dh}{dx}$

$\frac{Q}{w} = (-K)b\frac{dh}{dx}$

① transmissivity: prop. of material & size of aquifer how easily water can move thru. $T = Kb$

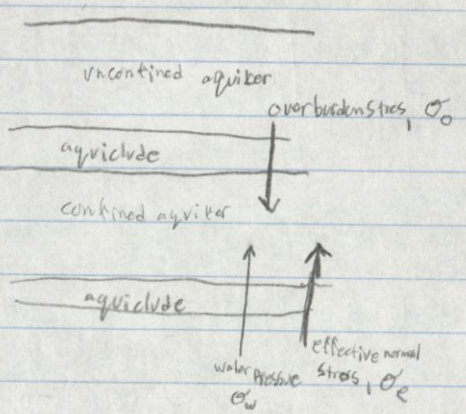
(2) Specific yeild = $\frac{\text{vol. of water "released"}}{\Delta \text{ head} \cdot \text{aquifer area}}$

$n = S_y + S_r$

n = total porosity; S_y = ; S_r = specific retention

1 & 2 used to determine if an aquifer is good or not.

- remove water out of storage.
- transfer water to area to remove it.



reciprocal of force units

$\beta = 4.6 \times 10^{-10} \left(\frac{m^2}{N}\right)$

Water

$\beta = \frac{-\Delta V / V}{\Delta P_w}$ (original Volume.)

$\beta \Delta P = -\Delta V / V$ increase P(f) then (-) in V = more density

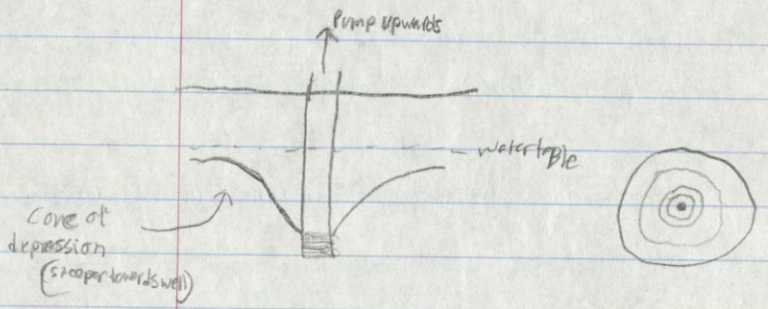
$\sigma_e = \sigma_o - \sigma_w$

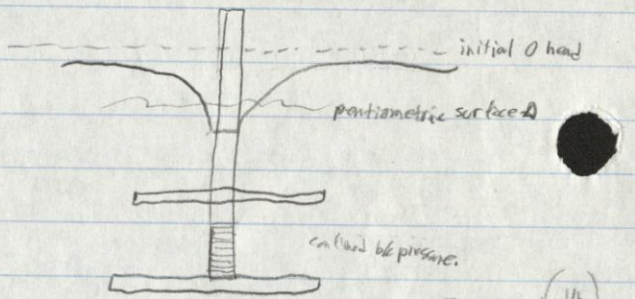
aquifer compressability: $\alpha = \frac{-\Delta b / b}{\Delta \sigma_e}$

$\propto \Delta \sigma_e = -\Delta b / b$ (σ_e dec. then b inc. aquifer expands)

Hvorslev Test — $K = \frac{r^2 \ln(L_e/R)}{2 L_e T_o}$

r = radius of well; R = radius of well screen; L_e = length to well screen; T_o = time for water to fall to 37% of initial Δ.





$Q = -kA\left(\frac{dh}{dx}\right)$

as A dec, $\left(\frac{dh}{dx}\right)$ inc, = no' steep (also inverse)

• Can use cone of depression to find K

Capture zone — GW watershed from cone of depression can also be used to suck up polluted sites

Subsidence — occurs wherever pumping occurs ex: loose P_w (pressure) ex: Norfolk sinking b/c pumping.

Intrinsic permeability = (Nd^2) (grain sort) & (grain diameter)

fluid = $K = \frac{\rho g}{\mu}$ viscosity, pressure, gravity

hydraulic conductivity = $K = (Nd^2)\left(\frac{\rho g}{\mu}\right)$

Structure

ex: anticline

Holy Trinity of Structural Geo

- Geometric Understanding — shape? what happened?
- Kinematic Understanding — movements/flows of material
- Dynamic/Mechanical — in time forces to move it/shape it. the stress

Compression stress to do it

ex: build mountains cause it

Allochthonous – Rocks displaced from where found

Autochthonous – Rocks still located where found.

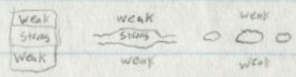
Azimuth System

N=0° S=180°

E=90° W=270°

Stress ↓ ← → ↑

Boudin – extention & sedimentation of pre existing layers



Rotation – movement based on fixed pivot point **Translation** – movement across distance versus direction **Dilation** – Δ in volume **Distortion** – Δ in shape

$\frac{L_f - L_0}{L_0(t)} =$ **Strain Rate** $= \frac{\text{amount of strain (\%) (elongation) as decimal}}{\text{time (s)}}$ Rate @ which deformation occurs

Magnetic MOR (+) amp = modern field. (−) amp = opposite

$\text{Stretch} = \frac{L_f}{L_0}$ $\text{Strain} = \frac{L_f - L_0}{L_0}$ = Δ in Length (1D) or Shape (2D-3D)

time = 1 yr = 3.2×10^7 seconds

stress = force/area force = mass · acceleration $9.8\,m\,s^{-2}$ = gravity a

Strain is what is left after a stress

Newton = $2\,kg \cdot 9.8\,ms^{-2}$

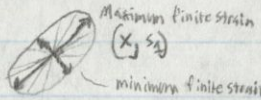
Pascal = Newton/m^2 or $kg\,m^{-2}\,s^{-2}$ or $kg\,m^{-1}\,s^{-2}$

$\frac{\text{pascal}}{10^6} = MPa$

Lithostatic Pressure $(\sigma_v) = \rho g h$ (rock density, gravity, depth below surface)

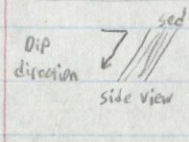
Stress ≠ Strain **Stretch** = $S = L_f/L_0$ Angular shear = $\Psi = (\psi_0 - \psi_f)$

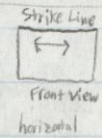
finite strain ellipse



Finite Strain Ration $R_s = \frac{X}{Z}$

ex: 060° 20° SE





BIF's – Magnetiterich w/ red chert (Banded Iron formation)

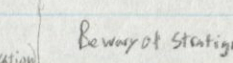
Geologic Contact – boundary btw geo units. **Geo Units** could show grade, rock types, tectonics, metamorphism, igneous, stratigraphic

4 Types of Geo Contacts

1. **Stratigraphic/sedimentary contact** = sed. layers on sed. layers (no truncation)
2. **Igneous/Intrusive Contact** = on dykes or igneous or metamorphic rock younger than sed on top of it.
3. **Tectonic/Fault Contact** = Rocks juxtaposed by fault/tectonic process
4. **Erosional/Unconformity Contact** (sed on igneous) = erosion contex flattens out beds can have truncation

ex: petersburg basin coals, then seds depo, then erode, then new seds depo.

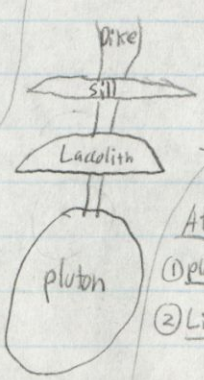
Way of Stratigraphy



Facing Indicators –

Sed. Structures – graded bedding, cross bedding, bottom marks, mud cracks, raindrop impressions

Igneous structures – pillow lava, flow top breccia, chill zones, columnar lava



Seds (country Rocks being intruded into)

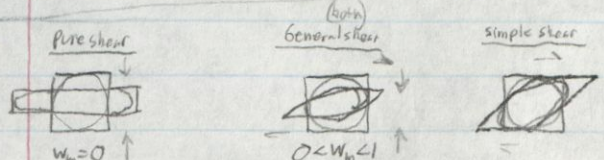
Diabase – chemically like basalt **Grainsizes** Gabbro < Diabase < Basalt

Xenolith – inclusion of country rock (assis) in an igneous body

Attitude or Orientation ex: 045° 20° SE

1. **Planar features** – strike, dip, & dip direction
2. **Linear features** – Trend & Plunge

ex: 325°, 17°



Deformation – broad w/o new material produced Slow pressure, Low temp, ex: fold beds
Metamorphism – Δ seds/units ex: dike of andesine in baked mudstone (hornfels) limestone → marble

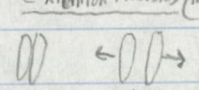
} 1 can occur w/o the other or together

2 things Geologic Map Pattern
① Underlying structure
② Topography

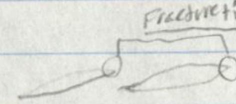
Fractures – cracks, if filled w/ minerals = veins

Extention Fractures (mode 1) | Sliding Fractures (mode 2 & 3)

Hands: 0. f. | 0. f.



Fracture tip (either fracture or vein)



Slickenslide is planar feature

Veins – from extention fracture is from precipitation mineral (not igneous)

Plumose Structures – feathery line ornimentation along fracture, marker for extension fractures (can be created in Lab)

dif. erosion rates for dif. materials

Fault scarp – Linear break in slope results directly from displacement along fault. Fault line Scarp – from dif. erosion. not all scarps displace

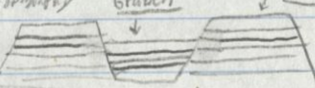
Fault rocks – faults have angular, poorly sorted grains in matrix, Brittle-Ductile transition 10-15m down

matrix – fine grained recrystallized materials
porphyroclasts – Large relic materials (minerals)

describing fold: ⊙ = arrow @ you ⊕ fletching away from you

Deformation causes rotation of rigid clasts = asymetric fabrics (Stair stepping technique) — top to left sense of shear.

Topography Graben Horst uplifted footwall

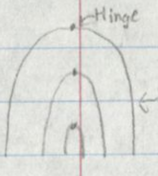


Graben are Normal fault rifts (Cont. MOR. (Rift basin, ocean))

S N Rock

Nappe – allocthonous rocks from Hanging wall (usually thrust). Window (fenster) – isolated erosional exposure of footwall below a thrust fault

Klippe ← erosional reminants of Haning wall from Reverse fault. Normal fault – remove strata Reverse fault – replicate strata >30° thrust fault <30°



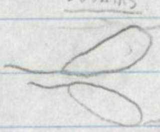
Hinge, Limb

Flysch = Deep marine sandstone & shale (deep marine foreland basin)
Molasse = Course grained terestrial seds. (overturned axial surface) (shallow marine, ss, shale)
Fold Axis = Linear layer Parallel to hinge

Hinge Line v. Fold Axis
– real boundry | – imaginary
– parallel folds | – parallel to overall shape of fold

Parallel but not the same

Boudins



Axial plane – Connects hinge points
Folds axis – folds hinge line fixed

Top to right = Dextral (right lateral)
opposite = Sinistral

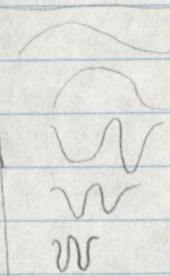
angular hinge, rounded hinge

Overturned folds W E

(verge to W)

Bedding
Foliation overturned 55
inclined 22
Lineation 13
Horizontal ⊕
hanging wall
vertical
Reverse →
Overturned 77
∴ Massive

field Notes
① Rock name w/ adj modifyer
② Color, mineralogy, (texture), Primary features, secondary features
③ interpretations



Gentle	180-135
Open	135-90
close	90-40
Tight	40-1
Isoclinal	(limbs parallel)

Isotropic – characteristics in ∅ direction
no fabric or Metamorphism only igneous cooling (massive)

Anticline (plunging) Syncline plunging

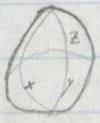
perpendicular to veins & joints

Stylolite – irregular discontinuity dissolution of soluble minerals during diagenesis. → Anti cracks form. filled in w/ insoluble materials

Blueschist chemically like basalt. only found in subduction zones. Low Geothermal Gradient high P. & Low T.

Mushwad – 15yr term deformation style/midstone

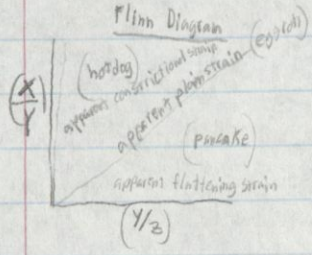
Strain Elipsoid
$X \geq Y \geq Z$



Isotherm – Contours of temperatures

Wadati-Benioff zones – earthquakes foci here during subduction

Flinn Diagram



Hotdog	Constrictional	$X > Y, \sim Z$	elongate 1 shorten 2	has lineation no foliation
eggroll	Plane	$X > Y > Z$		foliation & lineation
Pancake	Flattening	$X, \sim Y > Z$	elongate 2 shorten 1	foliation, no lineation

π-girdle is a great circle from lineated pebbles

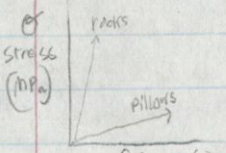
planar structures have been folded

Terrane – crustal region w/ rocks w/ dif. ages, stratigraphy & history compared to surrounding terranes. separated by faults/sutures boundaries

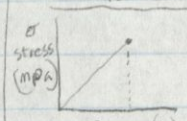
Rheology – study mechanical prop. of solids, fluids, gasses

Strength – ability of material to support differential stress. (Max stress before material undergos brittle/flow)

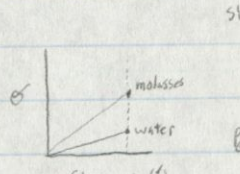
Elastic Behavior – stress & strain related but can revert to original strain. (Seismic wave pass through) $\sigma \sim \varepsilon$ $\sigma = E\varepsilon$ E = young's modulus



Permanent Deformation – permanent strain @ certain stress



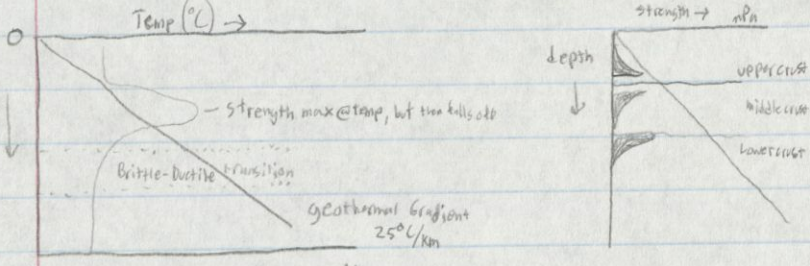
(folds, etc) Viscous behavior



Slope of linear velocity

$\sigma = \eta\dot{\varepsilon}$

η's = units for velocity
$\Leftrightarrow$ $Kg\,m^{-1}\,s^{-1}$



Plumb bob – weight on string measure angle

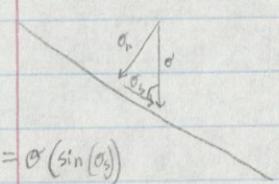
Depth of Compensation – larger depth = less density
less depth = more density

Isostasy – tendency of Earth's crust eqvilibrium w/ underlying material

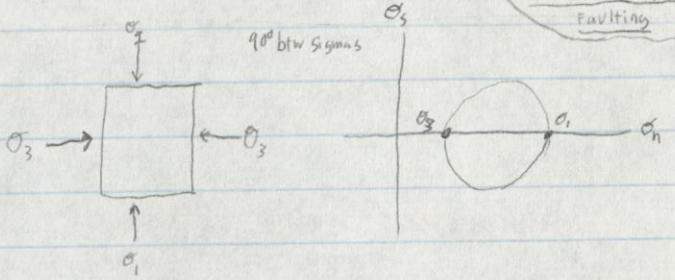
Anderson Theory of Faulting – orientation of σ^1 on Earth's crust

Normal = vert σ^1 = ↓
Reverse = horz σ^1 = → ←
Shear = lateral = ↗ Top

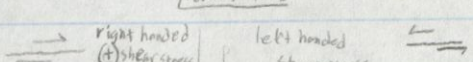
Normal stress (σ_n)
Shear stress (σ_s)



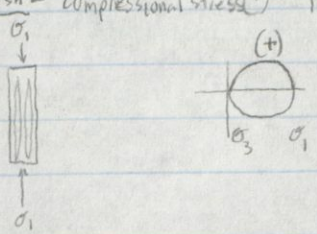
$\sigma_n = \sigma(\sin(\sigma_s))$
$\sigma_s = \sigma\cos(\sigma_n)$



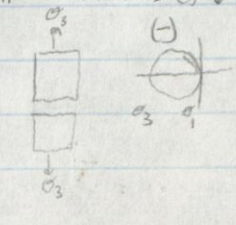
Normal Stress



Push = Compressional stress (+)



Pull = tensile stress (−)

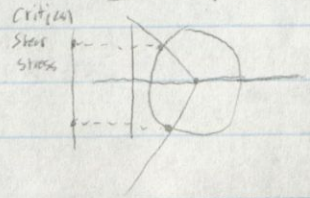


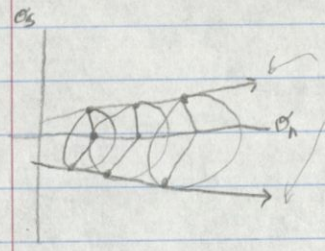
permanent deformation

Longitudinal splitting – parallel on long. direction

rock 10–15 x stronger in compression than tension

Biaxial compression test

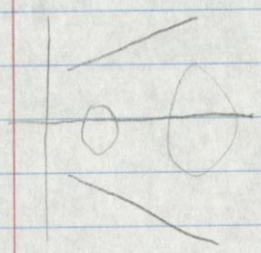




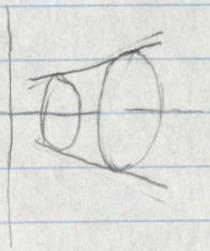
Critical shear stress points form a line = called failure envelope

$\sigma_s^* = c + \mu\sigma_n$ σ_s^* = critical shear stress c = cohesion (y-int)

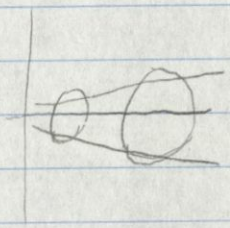
μ = coefficient of internal friction σ_n = normal stress



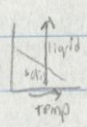
Stable state of stress
- No fractures



Critical state of stress
- Fractures form

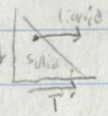


Unstable state of stress
- Fractures form

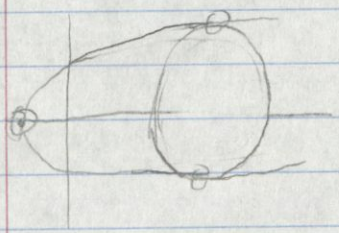
Magmatic decompression – 

occurs on subduction zone

ribbon of continents

Thermal melting – 

Anticlinal Stack – Anticlines form as sed layers thrust up over footwall



Shear fracture
normal stress = high
Shear stress = zero.

Duplex – Bunch of overlapping faults

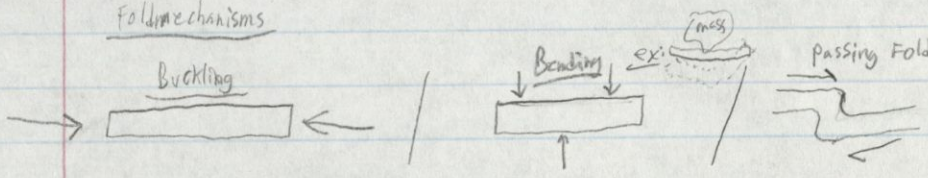
Tectonic Environments
- passive margins
- Fold/thrust belts
- Continental Rift basins
- ophiolites
- Cratons

Brittle-Ductile Transition — 10-15 km deep. where mylonites form in ductile zone. Brittle zone for fractures

Dip Slip — linear structure trend & dip direction

Oblique slip — intermediate

Fold mechanisms



Sigma 1

(σ_1) Compressional stress

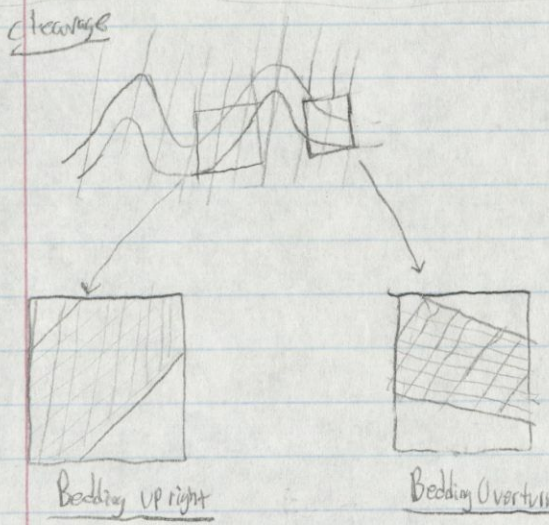
Contractional strain structures,

deformation in dif. ways
(1) volume Loss (pore space) (3) folds
(2) pure shear (4) reverse faults

Foliation — (general term) planar fabric in deformed rock (mostly igneous rocks)

Cleavage — Low Grade conditions rocks splits on planes (fine grained)

Exhumation — to re-expose @ surface

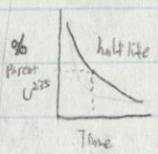


Cleavage angle > bedding angle

Cleavage angle < bedding angle

$\frac{-dP}{dT} \propto P$ (amount there)

$P = U^{235}$ amount



ending P. material: $P = P_0 e^{-\lambda t}$ (initial P. material; amount now)

$-dP/dT = \lambda P$

λ = decay constant

P = # radioactive parent atoms @ time (t) (P_0) Parent material @ t = 0

$Ln(2) = \lambda T_{1/2}$ $\quad T_{1/2} = \frac{Ln(2)}{\lambda} = \frac{0.693}{\lambda}$

Time = $\left(\frac{1}{\lambda}\right) \times Ln\left(\frac{D}{P} + 1\right)$

Time

daughter/parent ratio

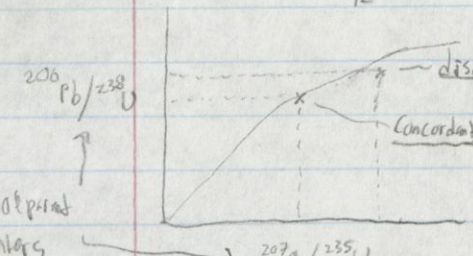
Zircon mineral $(ZrSiO_4)$ (igneous) $<< 1\%$ in granite

high (>700°C) Closure Temp

$^{238}U \rightarrow {}^{206}Pb$, $T_{1/2} = 4.46$ GA

$^{235}U \rightarrow {}^{207}Pb$, $T_{1/2} = 704$ MA

$^{40}K \rightarrow {}^{40}Ar$, $T_{1/2} = 1.256$a



Detrital zircons — in Sed. rocks show age of igneous form.

provenance — tell us about source material age.

youngest grain age puts cap on creation age.

Closure Temperature — temp. P/D ratio cease to form minerals

below it = P/D no escape system; above it P/D can escape

Closed system — Open system

Crystal habit locked in

? Crystalization Age — temp when crystals form from @ year cooling magma temps.

Cooling Age — temp when mineral becomes a closed system.

Stylolites (Anti-cracks) — take demineralized anticracks perpendicular to σ_1

verses N — anticline

verses N — syncline

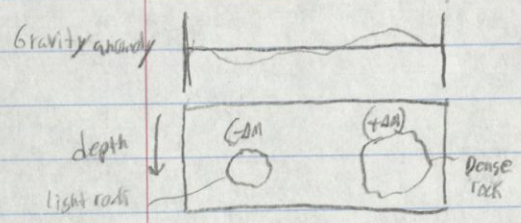
verse @ other material

Schlieren – elongate/tabular concentrations of MAFIC materials in pluton. ie Banded granite.

Magnetism

Gravity weight = force = ma @ sea level on equator $g = 978 cm s^{-2}$ $Gal = 1 cm s^{-2}$ $milliGal = 1/1000\ cm s^{-2}$

Gravity related to mass/density



earth's magnetic field 0.3–0.6 Gauss

Unit for magnetic fields = Tesla, nano Tesla (nT)/Gauss/Gamma = 10^{-5} Gauss

Induced Magnetism – materials only magn. within presence of Ambient magnetic field.

Mafic & ultra Mafic rocks

$\vec{F}_{amb}$ ↓↓↓↓ $\vec{J}_{ind}$

take away mag. field → Loose magnetism

Magnetometer – total intensity of mag. fields related to induced magnetism @ rocks near surface.

Permanent Magnetism – material retains mag. even w/ removal of mag. field

$\vec{F}_{amb}$ ↓↓↓↓ $\vec{J}_{ind}$

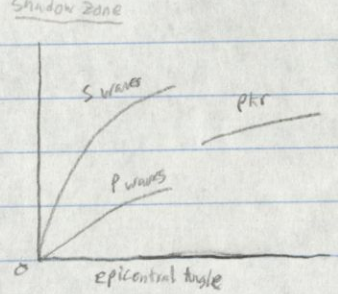
take away magnetism → $\vec{J}_{ind}$ still magnetic

Seismograph

Linear – dots, use E/W ref.

Planar – lines, use N/S ref.

Earthquakes



Body waves { S-wave (shear) ⇝ slow ; P-wave (compression) →|→ Compresses faster than dilates

elastic deformation – returns to original shape

Surface waves ⇝ Top view → ⇝ like snakes

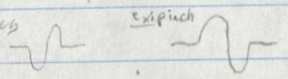
Local Richter Magnitude (M_L) Log of max. seismic wave amplitude (10x increase = +1 magnitude)

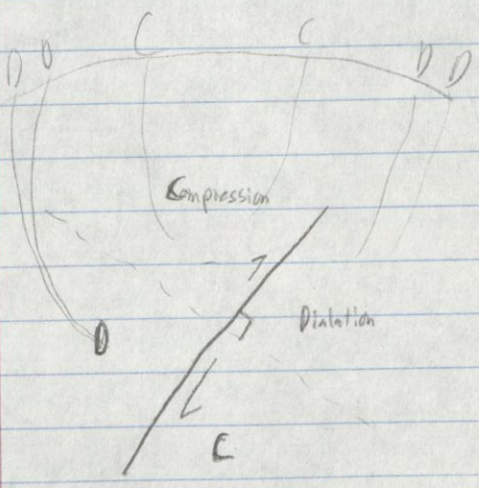
3.0 = felt locally, 4.5 = minor damage, 5.5 = moderate damage, 6.5 = very damaging, 8.0 = catastrophic damage

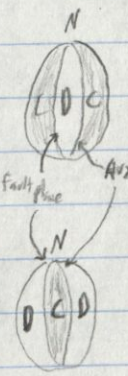
250 cm/s^2 significant

gravity is 980 cm/s^2

Seismograph 1st recordings Dilation ↑ Compression

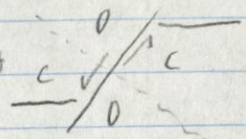




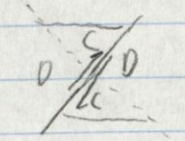


D → C ← D

Normal Fault

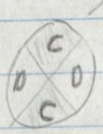


Reverse Fault



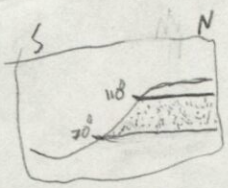
Faults & Auxillary planes could be switched

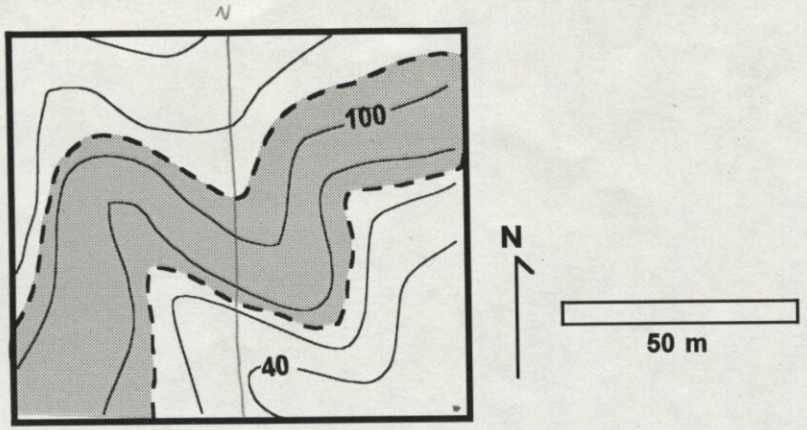
or



↿⇂ or ⇆ **Strike-slip**

gray could be horizontal, vertical, or inclined.



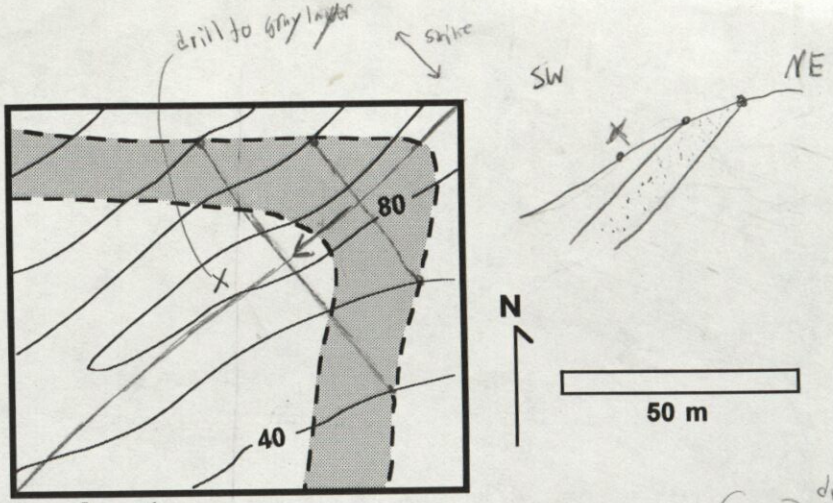


Approximate Strike & Dip of Layer

S

⊕ horizontal bedding

if contact is parallel w/ contour line = horizontal



Approximate Strike & Dip of Layer

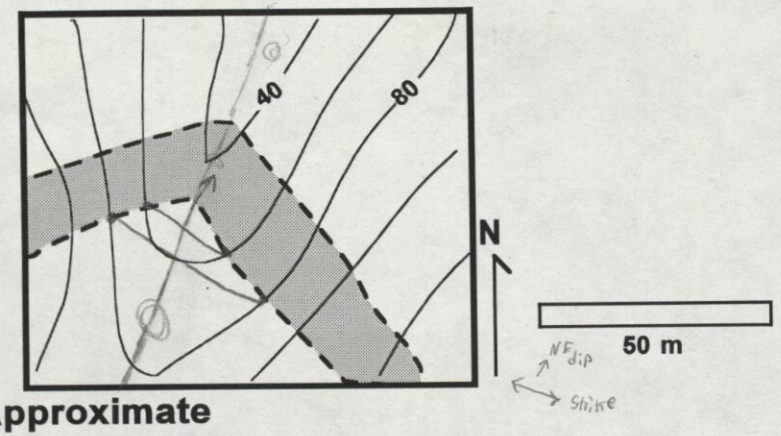
dip triangle

strike to NW dip to SW

320° 35° SW

35 inclined bedding

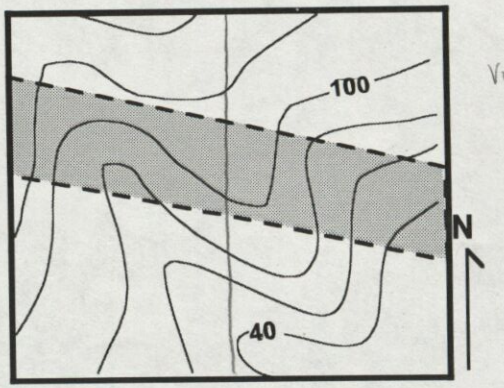
Sds always (probably) dip ~~slope~~ downstream.



Approximate Strike & Dip of Layer

300° ~~350°~~ NE

rule of Vs for dipping strata



Approximate Strike & Dip of Layer

120° 285° dips vert. ~90°

vertical beddings

MINERALS IN ROCKS

Minerals are the constituents of rocks, which make up the entire inorganic, solid portion of the earth. Mineral formation and rock formation are, in fact, one process. To know minerals, therefore, it is important to know rocks. A single mineral may form a rock, but usually rocks are cohesive aggregates of two or more minerals. Depending on how they were formed, rocks are divided into three types: igneous, metamorphic, and sedimentary.

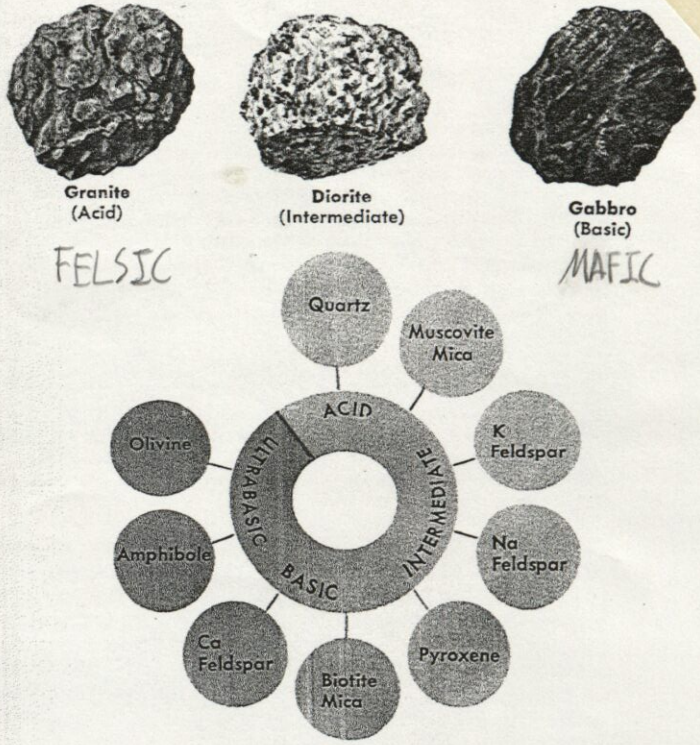
IGNEOUS ROCKS are formed by the cooling and hardening of magma, a complex molten material that originates within the earth. Some important types of igneous rocks are shown in the illustration on the facing page. The major mineral constituents of acid, intermediate, and basic rocks shown provide the basis for the classification given on page 9.

IGNEOUS MINERALS important in the formation of igneous rocks are relatively few in number. This is because the magma from which the minerals crystallize is rich only in certain elements: silicon, oxygen, aluminum, sodium, potassium, calcium, iron, and magnesium. These are the elements that combine and form the silicate minerals (pp. 154-227). A limited number of the silicates —the olivines, pyroxenes, amphiboles, micas, feldspars, and quartz—account for over 90 percent of all igneous rocks.

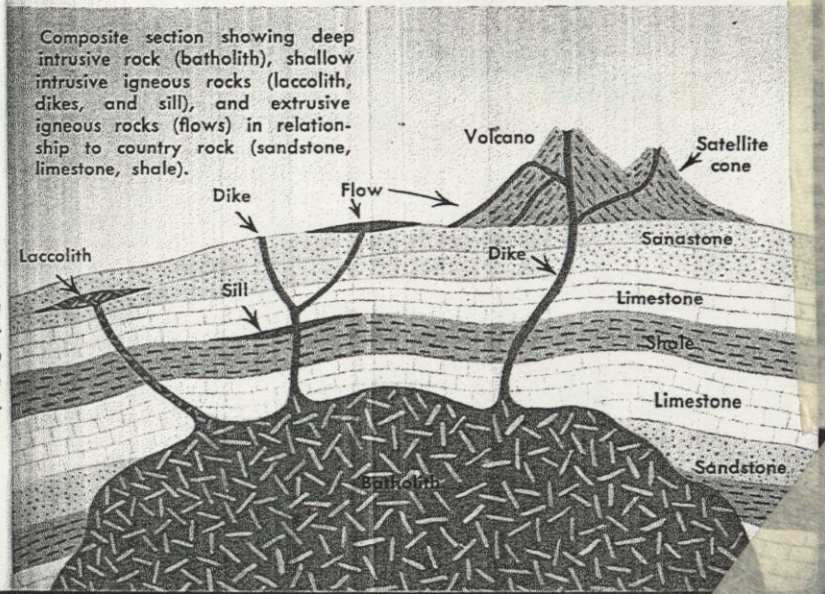
As magma cools, minerals crystallize at different temperatures. Olivine and calcium feldspar form at high temperatures and may separate early from the melt. Other minerals solidify as the temperature falls (see Bowen's Reaction Series, pp. 82-83). The last to crystallize are potassium feldspar, muscovite mica, and quartz, the major constituents of granite. Finally, water in the magma, carrying valuable metals and sulfur in solution, moves outward through fractures in the surrounding rock and deposits sulfides in veins. The water is also important because it affects the temperature at which crystallization occurs and the types of minerals formed during cooling.

INTRUSIVE IGNEOUS ROCKS, also called plutonic rocks, crystallize from magma that cools and hardens within the earth. Surrounded by pre-existing rock, called country rock, the magma cools slowly. As a result, these rocks are coarse-grained.

Central cores of major mountain ranges consist of large masses of plutonic rock, generally granite, intruded as a part of the mountain-building process. When exposed by erosion, these cores, called batholiths, may occupy millions of square miles of surface area. Offshoots of batholiths bear different names, such as laccoliths and sills, depending on their size and their relationship to the country rock. The term abyssal is commonly used to describe coarse-grained rocks formed at depth; hypabyssal is used to describe intrusive rocks formed near the surface.



IGNEOUS ACTIVITY



EXTRUSIVE IGNEOUS ROCKS, also called volcanic rocks, are formed at the earth's surface as a result of volcanic activity. Like batholith formation (p. 6), this activity is associated with mountain-building forces within the earth. Temperatures only a few miles beneath the earth's surface are higher than the temperatures at which most rocks would melt at the surface. The below-surface rocks remain solid, however, because of the pressure exerted by overlying rocks. If the rocks fracture—as the result of mountain-building forces, for example—the pressure may be released, and a sizable volume of rock will melt. The resulting magma will be forced through the fractures to the surface, forming a volcano.

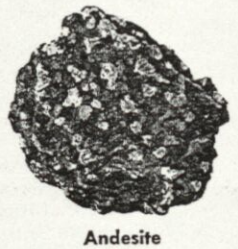
Molten rock, or lava, will flow from the volcano and spread onto the ground. Because the lava cools and crystallizes rapidly, it is fine-grained. Material may be blown violently from the volcanic pipe as blocks, pellets, and dust, or as a liquid that hardens before it falls to the surface. These pyroclastics may fall nearby, forming part of the volcano, or may be spread great distances by winds.

CLASSIFICATION of the many and greatly different kinds of igneous rocks can provide important information as to the conditions of formation. Two obvious variables that may be used as criteria for classification are particle size, which depends largely on cooling history, and composition, both chemical and mineralogical. Because feldspars, quartz, olivines, pyroxenes, amphiboles, and micas are the important minerals in the formation of igneous rocks, they are basic to the classification of those rocks. All other minerals are nonessential (accessory).

In the simplified classification on the opposite page, rock types are separated on the basis of the type of feldspar present, the presence or absence of quartz, and, in rocks with no feldspar or quartz, the type of iron and magnesium minerals present. Rocks with crystals large enough to be seen by the eye are called phaneritic; those with crystals too small to be seen are called aphanitic. In general, phaneritic implies an intrusive origin; aphanitic, an extrusive origin. Porphyritic refers to crystals embedded in a fine-grained rock. More detailed classifications using these terms are given in geology and petrology texts.

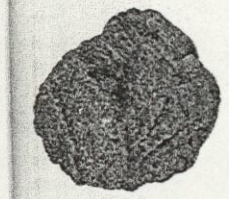
GRANITES show evidence of being the result of either igneous or metamorphic processes. Some granites obviously have crystallized from a melt; blocks of partially assimilated country rock may be found in granite, clearly indicating that the country rock fell into a liquid magma that hardened around it. Other granites, however, bear evidence of having been formed by metamorphism (p. 10); variations in composition of pre-existing sedimentary rocks are reflected in banding preserved in the granite. The conversion of sedimentary rock to granite by metamorphism is called granitization.

Rhyolite
(Acid lava)

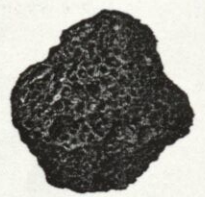


Andesite
(Intermediate lava)

Basalt
(Basic lava)



Tuff
(Cemented ash)



Cinder
(Pyroclastic debris)

Obsidian
(Volcanic glass)

EXTRUSIVE IGNEOUS ROCKS (Fine grained Crystals)

CLASSIFICATION OF IGNEOUS ROCKS

FELSIC MAFIC

Decreasing particle size (Faster cooling rate)	Decreasing silica content: Acid	Intermediate	Basic
Intrusive	Granite	Diorite	Gabbro
Extrusive	Rhyolite	Andesite	Basalt
Volcanic debris	Ash, Cinders, Blocks, Bombs Composition varies widely		

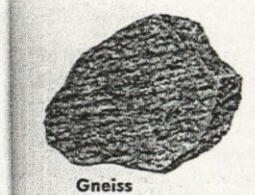
METAMORPHIC ROCKS

Rocks formed under one set of temperature, pressure, and chemical conditions and then exposed to a different set of these conditions may undergo structural and chemical changes, without melting, that produce rocks with different textures and new minerals. This process is known as metamorphism (change in form). Metamorphic rocks are formed deep beneath the earth's surface by the great stresses and high pressures and temperatures associated with mountain building. They are also formed by the intrusion of magma into rock, particularly at the place of contact where the temperatures are high. The study of metamorphic rocks provides valuable information about temperatures and pressures at great depths. Laboratory studies of the stabilities of minerals at temperatures and pressure similar to those within the earth are essential.

METAMORPHIC MINERALS form only at the high temperatures and pressures associated with metamorphism. Among these are kyanite, staurolite, sillimanite, andalusite, and some garnets. Other minerals—the olivines, pyroxenes, amphiboles, micas, feldspars, and quartz—may be found in metamorphic rocks, but are not necessarily the result of metamorphism. These minerals, formed during crystallization of igneous rocks, are stable at high temperatures and pressures and may remain unchanged during metamorphism of the rock. All minerals, however, are stable only within certain limits of pressure and temperature. Thus the presence of some minerals in rocks indicates the approximate temperatures and pressures at which the rocks were formed.

RECRYSTALLIZATION is the change in particle size of minerals during metamorphism. Small gray calcite crystals in limestone, for example, change to large white crystals in marble. Both temperature and pressure contribute to recrystallization. High temperatures allow the atoms and ions in solid crystals to migrate, thus reorganizing the crystals. High pressures cause solution of crystals at their contacts and deposition in the pore spaces between them.

FOLIATION is a layering in metamorphic rock. It occurs when a strong compressive force is applied from one direction to a recrystalling rock. This causes the platy or long crystals of such minerals as mica and tourmaline to grow with their long axes perpendicular to the direction of the force. The result is a banded, or foliated, rock, the bands showing the colors of the minerals that form them. Rocks subjected to uniform pressure from all sides or lacking minerals with distinctive growth habits will not be foliated. Slate is a very fine-grained foliate. Phyllite is a coarse foliate, schist coarser, and gneiss very coarse. Marble is commonly a nonfoliate.



Gneiss
Coarse banding

Schist
Fine banding

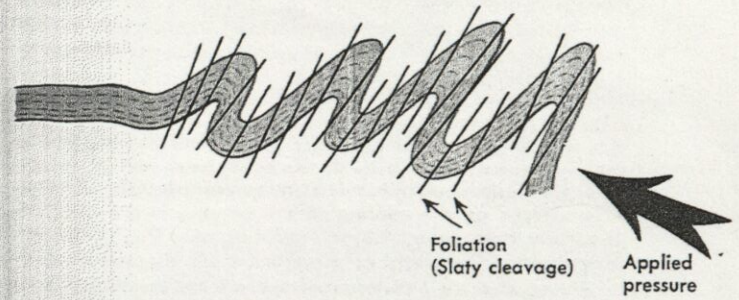
Slate
Very fine banding

Limestone (Fossiliferous)

Heat and Pressure

Marble

FOLIATION OF ROCKS



ORIGIN OF METAMORPHIC ROCKS

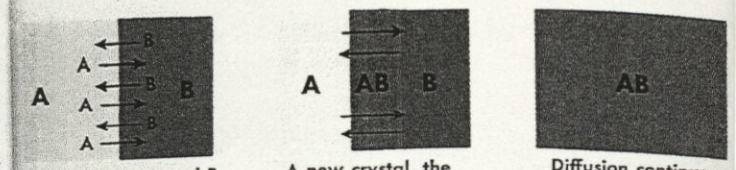
Rock type	Increasing temperature and pressure →			
Shale	Slate	Phyllite	Schist	Gneiss
Sandstone	Quartzite			
Limestone	Marble			
Basalt	Schist		Amphibolite	
Granite	Granite		Gneiss	
Coal	Peat	Lignite	Bituminous	Anthracite

SOLID-STATE REACTION is one of the important mechanisms of metamorphism. It is a chemical reaction between two minerals without either of them melting. In the process atoms are exchanged between the minerals, and new minerals are formed. Consider the minerals quartz and calcite. Each is stable alone at high temperatures. Together in a siliceous limestone, they do not change at low temperatures, but at high temperatures they react with one another and form the metamorphic mineral wollastonite. The chemical equation of the reaction is: SiO_2 (quartz, solid) + $CaCO_3$ (calcite, solid) ➤ $CaSiO_3$ (wollastonite, solid) + CO_2 (carbon dioxide, gas). Many complex high-temperature reactions take place among minerals, and each mineral assemblage produced is a clue to the temperature and pressure at the time of metamorphism.

METASOMATISM is a drastic change in the bulk chemical composition of a rock that often occurs during metamorphism. It is due to the introduction of chemicals from other rocks. Water can transport these chemicals rapidly over great distances. Because of the role played by water, metamorphic rocks generally contain many elements that were absent from the original rock and lack some that were originally present. The introduction of new chemicals is not necessary for recrystallization and solid-state reaction to take place, but it does speed up metamorphic processes.

CONTACT METAMORPHISM describes the chemical changes that take place when magma is injected into cold rock (country rock). These changes in the rock are greatest wherever the magma comes in contact with it, for temperatures are highest at this boundary and decrease with distance from it. Around the igneous rock formed by the cooling of the magma is a metamorphosed zone called a contact metamorphic aureole (halo). Aureoles are important in the study of metamorphism because a single rock type may show all degrees of metamorphism from the contact area to the unmetamorphosed country rock some distance away. Formation of important ore minerals may occur by metasomatism at or near the contact; limestone is particularly susceptible to this type of mineralization.

REGIONAL METAMORPHISM, in contrast to contact metamorphism, involves changes in great masses of rock over wide areas. The high temperatures and pressures in the depths of the earth are the cause. If the resulting metamorphosed rocks are uplifted and exposed by erosion, they may cover many thousands of square miles. Their mineralogy and texture provide important information about mountain building and earth processes. The metamorphism, however, destroys features that would have revealed the rock's previous history. Recrystallization destroys fossils and sedimentary textures; solid-state reaction and metasomatism change the original compositions.

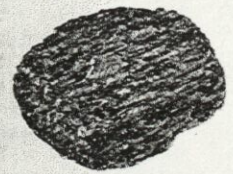


On heating, A and B diffuse through the solids across crystal boundaries.

A new crystal, the compound AB, forms between the crystals.

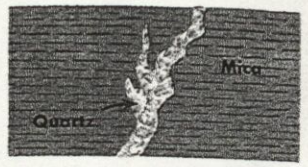
Diffusion continues until the original crystals are fully reacted.

THE SOLID-SOLID REACTION A + B ⟶ AB

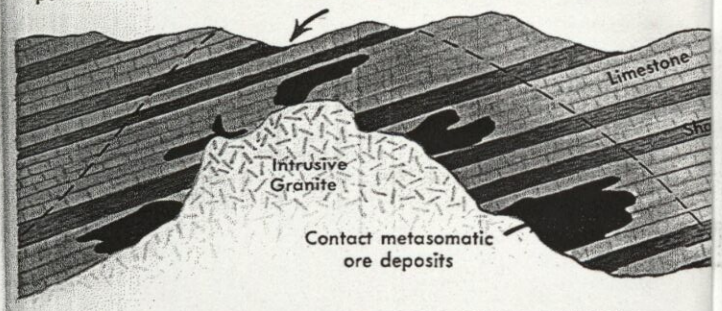


Augen Gneiss

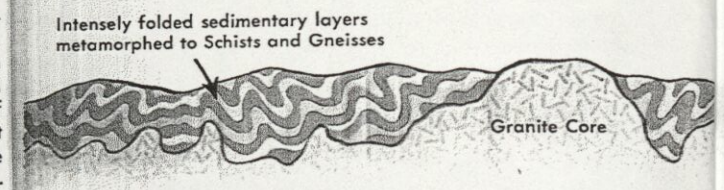
Potassium feldspar crystals formed by introduction of potassium



Quartz veinlet in Mica Schist formed by introduction of silica



CONTACT METAMORPHISM NEAR SMALL INTRUSIVE



REGIONAL METAMORPHISM ACROSS MANY MILES

SEDIMENTARY ROCKS

All rocks disintegrate slowly as a result of mechanical and chemical weathering. Rock particles—in the form of clay, silt, sand, and gravel—and dissolved materials are transported by the agents of erosion (water, ice, and wind) to new locations, generally at lower elevations, and deposited in layers. The deposited particles eventually become cemented together, forming **clastic** sedimentary rocks. The dissolved materials may precipitate as crystals that accumulate in layers in oceans and lakes and are cemented to form **chemical** sedimentary rocks.

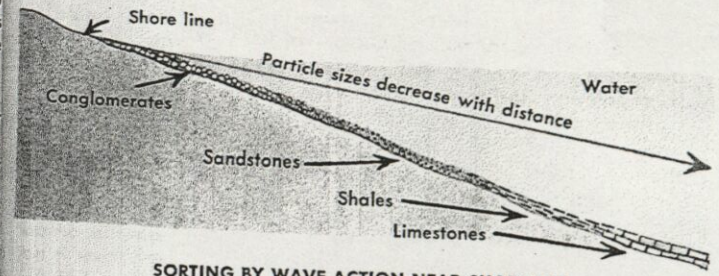
Sedimentary rocks provide abundant information about the most recent half-billion years of the earth's history. They contain in fossil form the preserved remains of evidences of ancient animals and plants. The manner in which particles of sediment are worn and deposited, the relationships of the different layers, the color and composition, the presence of ripple marks or raindrop impressions—these are among the features that enable geologists to reconstruct ancient landscapes and climates as well as the general sequence of geologic events.

MECHANICAL WEATHERING is the breakdown of rock into particles without changing the identities of the minerals in the rock. Ice is the most important agent of mechanical weathering. Water percolates into cracks and pore spaces; freezes, and expands. The force exerted is sufficient to widen cracks and break off pieces, in time disintegrating the rock. Heating and cooling of the rock, with resulting expansion and contraction, also helps. Mechanical weathering contributes further to the breakdown of rock by increasing the surface area exposed to chemical agents. The breakdown of rocks and erosion of the fragments has been greatly accelerated over the past several centuries by the activities of man through farming and construction.

CHEMICAL WEATHERING is the wearing down of rock by chemical reaction. In this process the rock's minerals are changed into finely divided products that can easily be carried away. Air and water are involved in the many complex chemical reactions which include oxidation, hydrolysis, hydration, and solution. Igneous minerals are unstable under normal atmospheric conditions, those formed at higher temperatures being more readily attacked than those formed at lower temperatures. Igneous minerals are commonly attacked also by water, particularly acid or alkaline solutions. All the common rock-forming igneous minerals (except quartz, which is very resistant) are changed in this way to clay minerals and chemicals in solution. Silica is leached from silicate minerals and removed as a colloidal material that can be deposited later as opal or chert. Clay, quartz, colloidal silica, and chemicals in solution—the common products of weathered rocks—are the building materials of the sedimentary rocks.

SIZES OF SEDIMENTARY ROCK PARTICLES

Name of particles	Diameter of particles 25.4mm = 1 inch		Sedimentary Rock
Boulders Cobbles Pebbles Granules	Greater than 256 mm 64-256 mm 4-64 mm 2-4 mm		Conglomerates (rounded) and Breccias (angular)
Very coarse sand Coarse sand Medium sand Fine sand Very fine sand	1-2 mm ½-1 mm ¼-½ mm ⅛-¼ mm 1/16-1/8 mm	Sandy	Sandstones
Coarse silt Fine silt	1/64-1/16 mm 1/256-1/64 mm	Gritty	Siltstones and Mudstones
Clay	Less than 1/256 mm	Smooth	Shales, Claystones



SORTING BY WAVE ACTION NEAR SHORELINE

Wave and current action is most vigorous near shore, finer particles are carried to deeper water

CONSTITUENTS OF SEDIMENTARY ROCKS

	Major Constituents	Accessory Minerals	
	Abundant	Less abundant	Less than 1%
Mechanically deposited	Quartz Clay minerals Micas Calcite	K-feldspar Plagioclases Rock fragments	Magnetite Tourmaline Garnet Amphibole Hematite Limonite Others
Chemically deposited	Calcite Dolomite	Quartz (chert) Gypsum, Anhydrate Halite Hematite	

TRANSPORTATION AND DEPOSITION of weathered particles is provided by water, wind, and ice. These agents reduce the size of the particles and deposit them in new localities. Sediments dropped by streams form alluvial fans, flood plains, deltas, and deposits in lakes and oceans (p. 15). Winds may move large amounts of sand and smaller particles. Glaciers transport and deposit great quantities of rock materials. Composition of the sediments provides clues to the nature of the original, or source, rock. Differences between successive layers indicate changes that have occurred with time.

PRECIPITATED SEDIMENTS are made up of sodium, potassium, calcium, magnesium, chloride, fluoride, sulfate, carbonate, and phosphate ions. Because these chemicals are very soluble in water, they can be removed from existing rock in solution. Once dissolved in water, they may be precipitated by inorganic processes in oceans or lakes, or may be extracted by living organisms. Calcite ($CaCO_3$), for example, will precipitate from solution in warm waters and settle to the bottom, where it consolidates into limestone rock. Corals, mollusks, and algae also remove $CaCO_3$ from solution. Halite and other very soluble salts normally precipitate only from bodies of water that have no outlet after evaporation produces a saturated solution. Limestone is by far the most abundant precipitate, but salt, gypsum, and phosphate deposits are common.

CLASSIFICATION of sedimentary rocks begins with the broad divisions of clastic and chemical rocks (p. 14), though there is no clear distinction between the two processes of deposition. Chemical rocks are classified on the basis of composition as salt, gypsum, limestone, chert, phosphate rock, nitrate beds, borate beds, etc. Specialized characteristics may be noted by such modifying terms as fossiliferous (containing fossils) and nodular (lumpy).

Classification of clastic rocks is more complex because of many variables. Particle sizes (average and range of sizes), composition of the particles, the cement, the matrix (smaller particles in the spaces among larger grains)—all must be considered. The Wentworth scale is a broad classification based on average particle size. Shale or mudstone, siltstone, sandstone, and conglomerate are names given to rocks with particle sizes ranging from very fine to very coarse. Shales, which consist mainly of clay materials with very fine grains of quartz and feldspar, are generally classified further only on the basis of composition and bedding. Coarser clastics are classified according to composition and particle sizes. Orthoquartzite is a very pure quartz sandstone; arkose, a sandstone with quartz and abundant feldspar; graywacke, a sandstone with quartz, clay, feldspar, and metamorphic rock fragments. The classification on the facing page provides only general terminology, without the specialized names or the descriptive adjectives that are commonly used.

Conglomerate

Sandstone

Shale

CLASTIC ROCKS

Limestone

Chert

Gypsum
Grand Rapids, Michigan

Rock Salt
Louisiana

Bituminous Coal
West Virginia

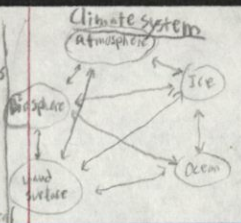
CHEMICAL ROCKS

CLASSIFICATION OF SEDIMENTARY ROCKS

Decreasing particle size	CLASTIC	
	Rock name	Particles
	Conglomerate	Granules
	Sandstone	Sand
	Siltstone and Mudstone	Silt
	Shale and Claystone	Clay

CHEMICAL	
Rock name	Composition
Salt	Halite ($NaCl$)
Gypsum	$CaSO_4 \cdot 2H_2O$
Limestone	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Chert	SiO_2
Borates, Nitrates, Phosphates	Many minerals

As in Cases
- plate tectonics
- Earth's orbit
- Sun strength
- Anthropogenic



Climate Δ

Paleoclimate – study of earths past climate prior to instruments.

Climate – composite Avg. long term conditions

Weather – short term fluctuations in climate variables

Steady state – system where input = output

Electromagnetic Radiation

high Energy shortwaves ← ins → Low Energy Longwaves

Blackbody – all objects absorb radiation & emit it @ full efficiency

Stefan-Boltzmann Law – hotter objects radiate more energy.

Wein's Law – hotter objects radiate mo' shortwave Energy.

$$\left[X \cdot Y / 5.67 \times 10^{-8} \left(W / K^4 \right) \right]^{.25}$$

Avg. Temp of Earth = 60°F, 15°C

Earth Recieves 1365 W/m^2 solar Constant E from sun. Dist. over the Earth $1365/4 = 340\ W/m^2$ to pot atmosphere anywhere on Earth

Either Reflected (albedo), scattered, absorbed

$$albedo = \frac{\text{reflected}}{\text{absorbed total}}$$

Longwave collisions → Vibrational E (in clouds) → Translational (E) heat back to planet.

Greenhouse effect – Lower atmosphere warmed by gases absorbing Longwave Rads. back to earth. transmit shortwave rads. (Trace gases < 1%)

Sun solar cycles Δ over decades 1367 / 1365 ∿ 2 W/m^2 Range

Warmer atmosphere = holl mo' clouds (water vapor) cause neg. albedo set rid of Rads.

Regional/seasonal E dist.

Polarity				
equator	parallel w/sun	March 21st	equinox	
	Cancer	June 21st	solstice	23½ N
equator	parallel w/sun	Sept. 22nd	equinox	
	Capricorn	Dec. 21st	solstice	23½ S

Summer = longer days; mo' sunlight b/c angle mo' heat (E)

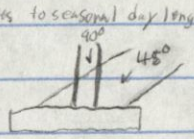
Winter = shorter days, less sunlight b/c angle less heat (E)

Circle of Illumination = ÷ globe by daylight/darkness Subsolar point = suns rays @ 90° on tropic of Cancer/Capricorn | Declination = lat. of subsolar point

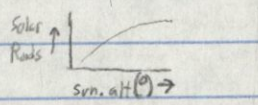
① Revolution 365.242 days ② Axial Tilt 23.5° tilt (daylength from sun angle) ③ Polarity orientation of axis, pointed to polaris } dist 340 W/m^2 b/c seasons

- solar angle relates to seasonal day length & amount E from sun.

CO2 & Methane in Troposphere cause vigorous mixing



① Beam Spreading Earth Rads hit surface less/more concentrated



② Beam Depletion Lower angles allow mo' solar Rads in atmosphere

③ % absorbed/reflected [mo' absorbed @ higher angle, mo' reflected @ lower angles] } to same albedo materials

In tropics
- Direct solar Rads.
- less seasonality
- mo' absorption

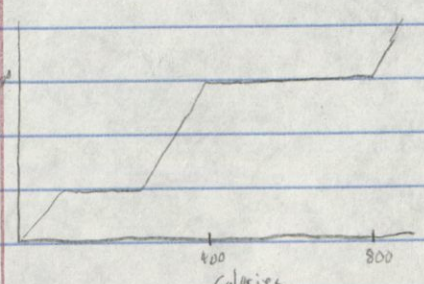
In High Lats
- indirect solar Rads.
- mo' seasonality
- mo' albedo

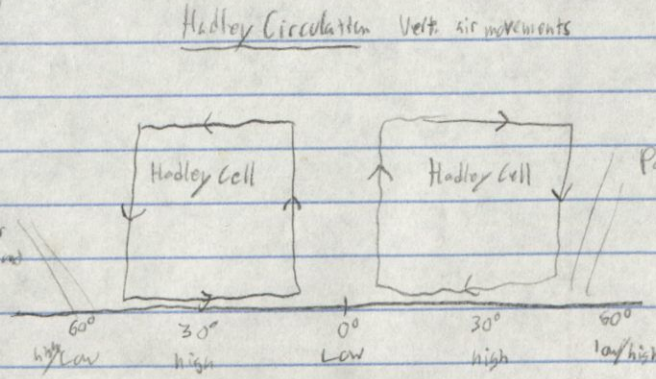
Climograph – monthly Avg. temp & precipitation @ certain location

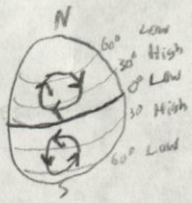
Sensible heat – heating of earths surface + lower parts of atmosphere (what you feel)

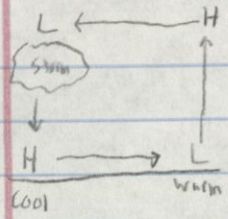
Latent Heat – E needed to Δ states of matter for water

Hadley Circulation Vert. air movements









Movements

Horizontal – pressure gradients (High to Low)

Vertical – (1) mechanically convergence – orographic / frontal boundaries

(2) Buoyancy (density) of air particles (uplifts subsiding)

high water amount

Cool air ← warm air

higher alt = cool air

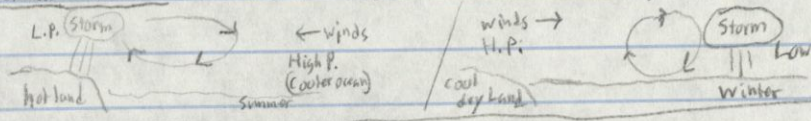
Sea level 1013.2 (mb) millibars

Coriolis Force – winds deflected b/c Earth rotates – N. Hem deflected to right, S. Hem deflected to Left

Inter Tropical Collision zone (ITCZ) ±30 lats.

– lower lats. – shorter response time + mo' magnitude

Monsoon Circulation – seasonal Δ in atmosphere circulation b/c uneven heating of land & sea – wet/dry phases – Land heats quicker than sea

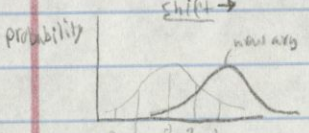


Ocean Circulations

Gyres – transport heat too circular – frictional drag from wind – density/salinity/temp in deep ocean – winds, coriolis forces – size of basin

wind direction → water direction

Surface currents – 50–100m depth. Ekman Spiral – Δ in flow direction btw surface ocean & depth. Net water mvt. = 90° from wind direction



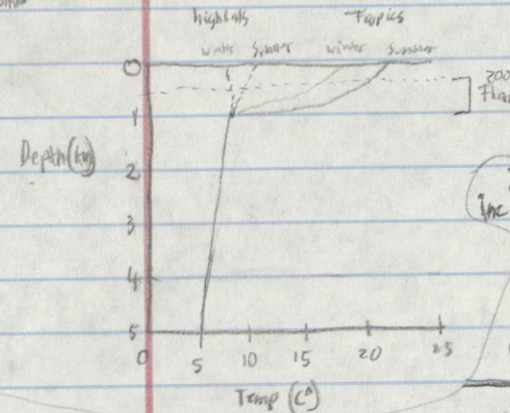
PDF – Probability Distribution Function (climate attribution)

Western Boundary – warm, fast, deep, narrow ex: Gulf stream, Kuroshio current — flow warm → poles

Eastern Boundary – shallow, wide, slow ex: Canary current, Ca current — flow poles → equator

Deep water forms in poles. Cold water sinks

Temp & salt = thermohaline circulation



Surface water mo' dense

(1) cool air cooled

(2) mo' evaporation = mo' salty

(3) less precipitation

(4) salt rejection from sea ice forming

Polar

1200–1500 yrs for ocean to turn over

(1) Upwelling – flow of cold water to surface

(2) Downwelling – sink of warm water

equatorial upwelling – converging wind fields

coastal upwelling – winds drives offshore surface ocean transport

Temp inc 1°C / century

Pacific Decadal Oscillation (PDO)

Cousin to ENSO (when el niño usually +PDO) varies 10–50yrs – warm waters in NE pacific.

El Niño Southern Oscillation (ENSO) 2–7yrs

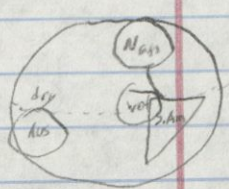
pumps up global T.

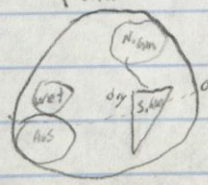
alt. surface ocean temp. & atmospheric pressure patterns in equator pacific in Dec–Feb.

3 phases (Neutral) | El Niño (warm phase) | La Niña (cold phase)

El Niño (warm phase):
- wet E. Pacific
- walker cells (low P./rain) on E
- dry W. Pacific
- reduced upliftings

La Niña (cold phase):
- dry E. Pacific b/c walker circulation ↑
- wet W. Pacific
- humbolt current from antarctica pushes warm water away on E. pacific





N. Atlantic Oscillation (NAO)

(Azores high) subtropical high pressures & Icelandic Low pressures → Iberian Peninsula

affects Westerlies · ctrl climate phenomenon of atlantic

Jet streams – narrow bands of strong upper level winds follow boundaries btw warm & cool air masses — polar & subtropic Jet ctrl temp.

NAO –

wet

L

dry N. Euro.

USA dry

Iberian Penn. wet

H

NAO +

dry

L

wet N. Euro

USA (wet too)

Iberian Penn. dry

H

Forcings: factors that cause Δ climate

1. Tectonic processes – crustal plates (10–100 Ma)
2. Earth's orbital Δs – (10–100 kyr)
3. Δs in sun strength – long 100s Ma / short 10–1000 yrs
4. Anthropogenic forcing – by product of humans

Response: climate Δ that occurs in earth's systems

1. Ice: albedo + air temp
2. Veg: CO_2 in land/sea, albedo
3. Atmosphere: clouds/water vapor
4. Oceans: temps + CO_2 in seawater stability
5. Land: temps + release CO_2 & CH_4 from permafrost/coal, albedo

Proxy: tangible record of forcing (cumulative rate of climate Δ)

Tree rings
Ice core
benthic core
Coral core

Quaternary pleistocene 2.6–.0115 Ma holocene .0115–present

- ~last 2.6 Ma, appearance of Ice age fluxes, 1st appearance N-Hem glaciers, interglacial/glacial cycles.

Occurance

atmosphere	hrs/weeks
Land surface	hrs/months
Ocean surface	day
veg.	
sea ice	
mnt. glaciers	
Deep oceans	
Ice sheets	

faster ↑ slower ↓ slow

Forcings for Quaternary affect seasonal dist. of solar E.

1. Revolution
2. Axial Tilt — how it varies (degrees)
3. polarity/orientation of earth's axis (~23,000 yrs)

Milankovitch cycles (yrs)

eccentricity	100K
Obliquity	41K
precession	23K

Δs in poles / mag.

Resolution – extent & clarity of climate info. resolved from archive.

1. Amount of disturbance/preservation of an archive
2. Rate it accumulates/grows/forms

Sediment archives – Lakes (seds, pollen grains (10Kyrs) fast sedimentation rates

Marine seds – Ma resolution slower sed. rates, not all marine seds alike

Isotopes for water — lighter →

^{16}O 99.8% ^{17}O 0.04% ^{18}O 0.2%

$\delta^{18}O$ is more or less $^{18}O/^{16}O$ ratio

ET more ^{16}O; precipitate ^{18}O first

Deepocean has more ^{18}O

Insolation affects monsoons

Foraminifera – shells made of calcite ($CaCO_3$) **Ice Rafted debris (IRD)** – in sea glaciers drop of debris

Rodbell 1999

El Niños → Lake cores 15 kyr. – precipitation & runoff rates recorded as more sedimentation. El niño had more.

Mayan Collapse – Ocean seds proxy for titanium. proxy = less rainfall = less Ti = Δs in ITCZ away from Cariaco basin

Hurricanes in Boston → Lake cores depo. organic laminations. Varve depleted annually b/c seasonal Δs in organic depo. ✱ written hist data confirms this.

African Drying Period – climate affect vegetation = affects humans. Δs in orbital precession flip monsoons cycles

long term drying. evidence: boreal fossils, saprapels, biowax, $\delta^{18}O$, Pacific Ocean Sea Surface temperatures

Ocean Core – $CaCO_3$ – ice volume (global)

Ice core – ice H_2O – global temps

Radio Carbon dating – annual layer counting ex: tree rings, coral bands, sediment cores, ice cores
– radiocarbon dating of isotope C_{14} to N_{14} 5,700 yrs ½ life effective range of 50K

Varves – annually deposited sed. layers in lake/marine env. (clay & silt depositing in single yr in nature) shows chronology of glacial seds. ^{18}O in benthic forams related to global ice totals

Oxygen Ratio in water

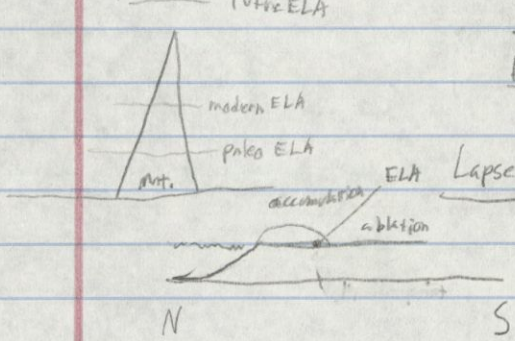
① mo' rain = lower $^{18}O/^{16}O$ ratio precipitation ② mo' cold = lower $^{18}O/^{16}O$ ratio precipitation.

Polar Amplification – their responses Δ @ lower amps. than global climate = cushioned

also air moves freely in ice/snow until 50m down. air is sealed in @ that depth. must use trapped ice for climat CO_2 ratios

Sintering Time of ice – time it takes for air bubbles to close & stop exchanging gas w/ atmosphere Low snowfall = 1000 yrs high snowfall = few decades

Deep Ocean – holds mo' CO_2 – deepwater formation – Biological pump holds mo' nutrients sequester ppm of CO_2



Glaciers – dense ice mass buckle under own weight

ELA = avg. temp = 0°C isotherm transitionary zone from ablation & accumulation

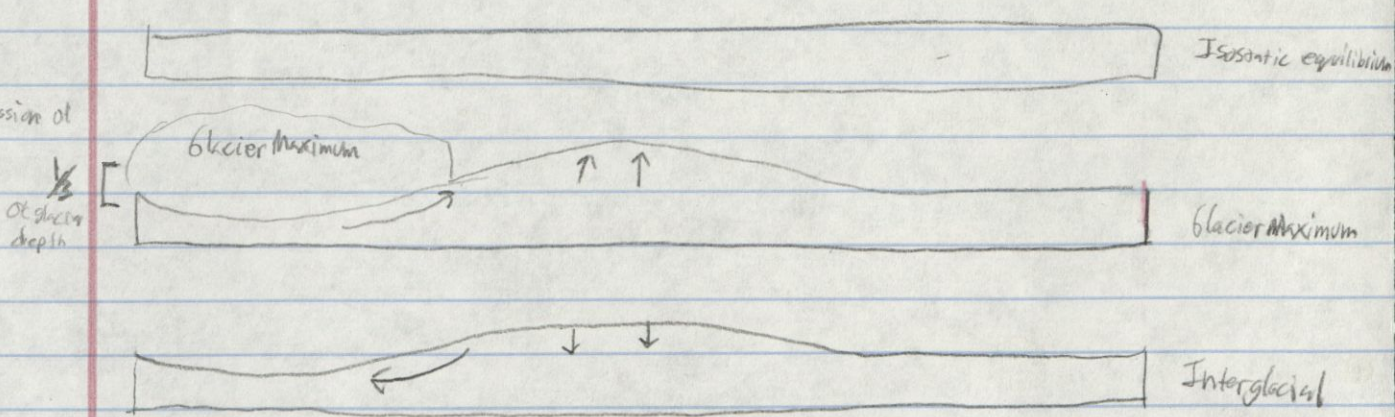
Lapse Rate higher elevation = lower temp −6.5°C/Km Lower ELA = Lower global temps.

polar Jetstream in VA b/c T dif's from poles to equator

Climate point – ELA meets ocean LGM ice on Land find: moraines, beach lines, isostatic rebound, Δ in sea levels

Isostatic depression

Near field Intermediate Far field (Δ's seen level in far field)



Return to Isostatic Equilibrium.

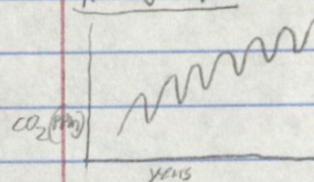
RSL = Relative Sea Level Δ's Hydro Isostatics affect sea water fills basins b/c Glaciers melt.

Rebound Δ's shorelines

Climate Δ

Carbon Cycle

Keeling curve upward trend w/ seasonal variabilities



Gigaton (Gt) 1 bn metric tons   1 metric ton = 1000 kg

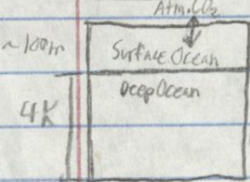
$1\,GtC \cdot \frac{44}{12} \frac{(\text{atomic mass } CO_2 = 44)}{(\text{atomic mass } C = 12)} = 3.67\,Gt\,CO_2$

$1\,ppm\,CO_2 = 2.13\,GtC$ or $7.81\,Gt\,CO_2$

Residence time = time material in reservoir
reservoir size ÷ flux (either in or out)

Inorganic → **Organic**

$6CO_2 + 6H_2O \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$



Biological Pump – CO_2 sink to deep ocean 50% of atmosphere CO_2 in deep ocean, becomes trapped as rock

Organic
(Oxidation) C erode to CO_2
(burial) buried as seds.

inorganic
Volcanism – melt rocks release gasses in air (~.15 Gt/yr)
chemical weathering – (~.15 Gt/yr) silicate rocks w/ acid

Chemical Weather

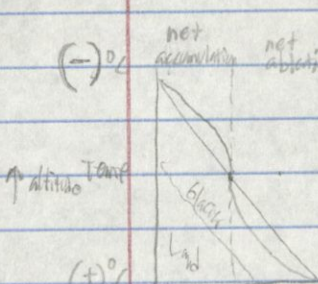
$\underset{\text{silicate bedrock}}{CaSiO_3} + \underset{\text{carbonic acid in soil}}{H_2CO_3} = \underset{\text{ions in water}}{HCO_3^- + Ca^{+2} + Si^{+4}} = \underset{\text{ocean deposition}}{SiO_2 + CaCO_3}$

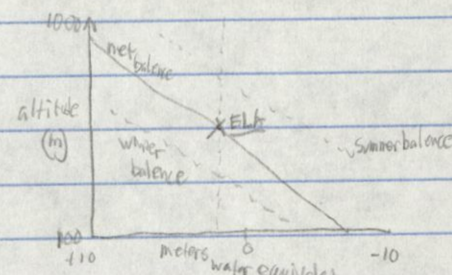
(A) physical & chem. – CO_2 + rainwater → Carbonic acid (H_2CO_3) dissolves $CaSiO_3$
(B) Transport – dissolved ions transported (acidify oceans) lowers ocean pH
(C) Deposition – Calcium Carbonate precipitates = limestone deposits

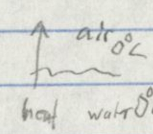
Cryosphere

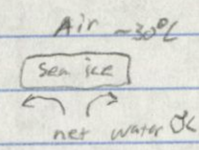
high albedo, permafrost traps methane CH_4 (GHG)
23 million km² in N. Hem.
[<0°C for 2 yrs.]

ELA – equilibrium line altitude
Sea level @ poles   20,000 @ equator









Sea ice forms (−1.8°C b/c salinity)

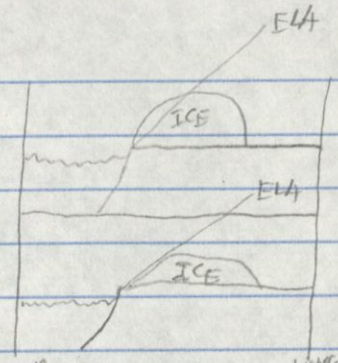
Carbon cycles Reservoirs

Faster ↑
- atmosphere
- Land surface
- Ocean surface
- Vegetation
- Sea ice —— Slower ↓
- mnt. Glaciers
- Deep oceans
- Ice sheets

Slow

Freezing Degree Days Σ of avg. daily degrees below freezing below years (all neg temps make pos FDD Σ)

Ice sheets – antartic & Greenland.



accumulation ← → ablation

delayed isostatic depression b/c ice sheet grows @ higher temps

Small Δs in Milankovich cycles with interglacial & glacial cycles

Speleothems — Cave Calcite drip formations records isotopic composition of groundwater
basically a tropical ice core, use stalagtites (often)

Low $\Delta^{18}O$ values in Ice Caves = higher global temperature

Low $\Delta^{18}O$ values in Benthic forams = low ice volume

Low $\Delta^{18}O$ values in Speleothems = high precipitation

climate point — where ELA is @ sea level can be the start of calving

① Overall dec. in Benthic ^{18}O ② Inc. Amplitude of warm & cool glacial/interglacial cycles ③ E-W gradient starts in Pacific SSTs

African Humid period (15-5 kyr) N. Africa & E. Africa abrupt @ 5kyr collapse of civilizations probably from precession.

Last Glacial Maximum 26-19 kyr Little Ice Age ~1100-1500

Polar Amplification — less gradient b/w pole to equator gradient stops global fires
higher polar to Equator gradient = more windy — expanded Loess deposits — N. agricultural productive soil

Eustatic = Global Laurentide Ice Sheet - Braided river system - lots of wind & sands

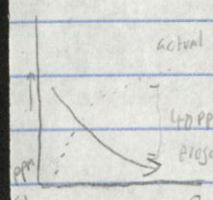
Input of Freshwater
- Rates of warming
- Meltwater Routes
- Proglacier Lake

Younger Dryas (11-13 ka) (Pleistocene-holocene boundary) N. hem cooling in Euro. b/c Atlantic meridional overturning proxy: cold tolerant pollen
(8200 yrs) - flood of freshwater in N. Atlantic from glacial Lakes

Deglaciation — albedo feedback = ice shrinks, less E reflected, — CO_2 feedback = less sequestered in deep ocean.

Meltwater Routes — pathways for meltwater to reach ocean as ice margin retreats ex: Laurentide meltwater down mississippi valley

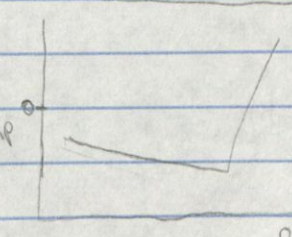
Meltwater Pulses — abrupt climate Δ of "Freshwater forcings" released from proglacial lakes/ice margins upsets ocean thermohaline circulation



6-10k (holocene) CH_4 & CO_2 increase. Inc. in human activity - deforestation - agriculture Medieval climate Anomaly - (1000-1300) warm period in Euro

Little Ice Age — cold period 1400-1900 A.D. adv. of glaciers in N.H. (low solar irradiance (low sunspots) w/ volcanism)

Hockey stick Curve made from
- treerings
- instrumental records
- polar ice cap records



CO_2 can Lag & lead temp in poles

Climate models – ÷ globe to biomes w/ smaller grids within it. tons of variables, all models are approximations
↳ hindcasts test past/historic/Paleoclimate

In models
① Boundary Condition – fixed conditions effects climate – land, oceans topography, land contour / ③ climate forcings
② Initial conditions – (temp, humidity, for e/ grid cell) / ④ feedback ⑤ sensitivity

RCP = Representative Concentration Pathways — 1m rise in sea level DOD = climate Δ affects conflict worldwide

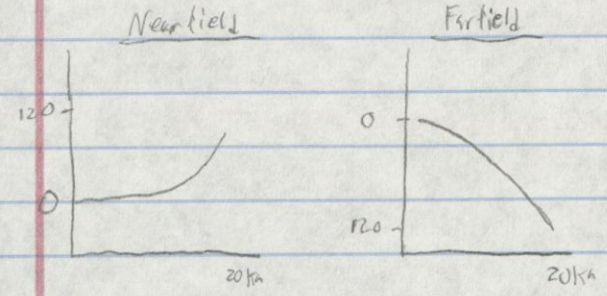
ppm CO_2 — wedges for stabilization triangle using mitigation & adapting techniques
temp

Top 3 fuel types for us. coal, oil/gas, nat. gas. US emits 20% global CO_2 (2nd to China) global 75% CO_2 output from devo. nations
US 18t CO_2e per capita

① Direct Regulations — Set fixed emissions rate
② Carbon Tax — tax on carbon content of fuels
③ Cap & Trade — set amount of emissions but can buy/sell excess permits

UNFCC UN Framwork Convention on climate change. 1997 formed
1998 kyoto protocol 190 members but no U.S. based on total E consumption by GDP – U.S. rejects any other method.
2015 Paris global warming >2°C to all biggest emitters – Trump pulled out of agreement.

Sea level Δs from past glaciation



Low ^{18}O benthic = high ice vol. + colder avg. temps

Low ^{18}O ice cap

0 & 60° wet more precipitation Seattle & equator

30° & 90° dry deserts Sahara & antarctic