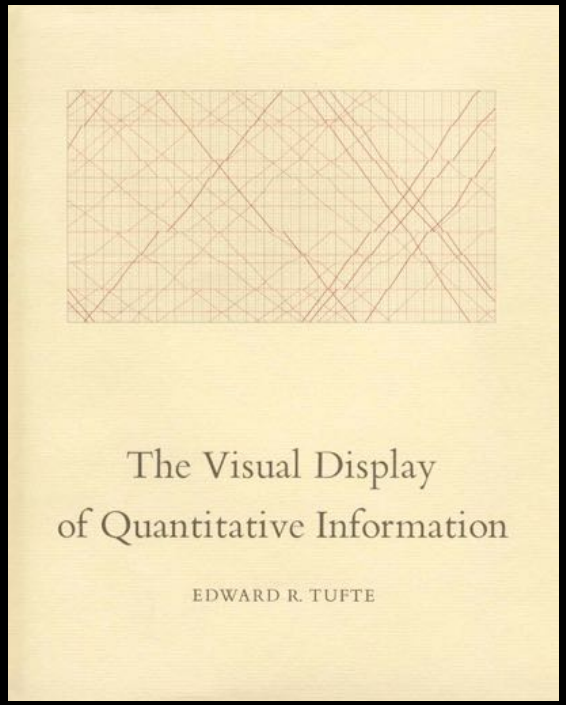
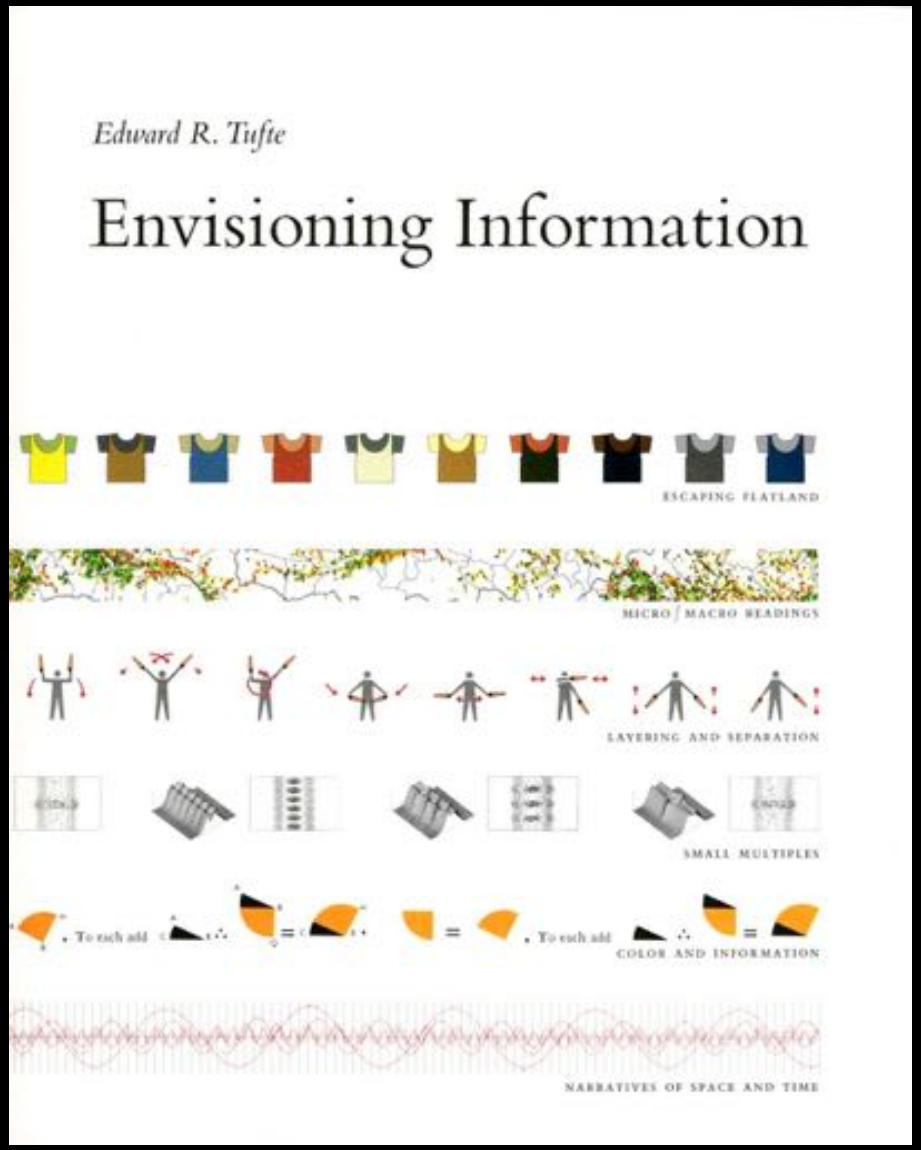
Tufte's Design Principles

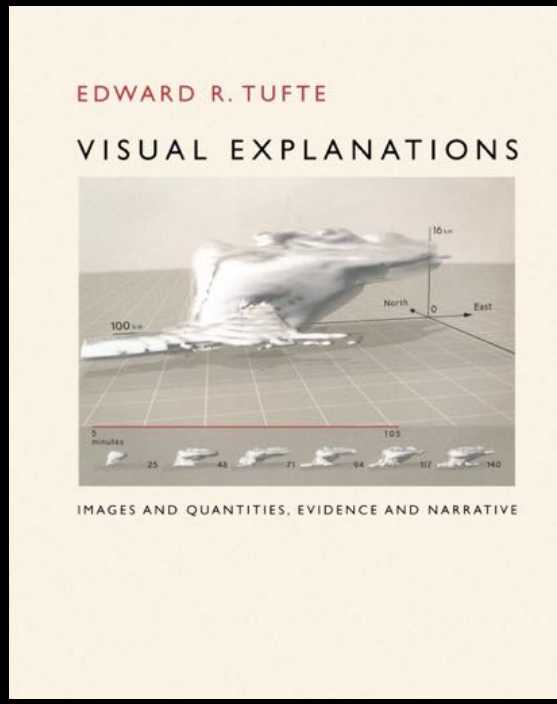
James Eagan

Adapted from slides
by John Stasko

Envisioning Information







Graphical excellence is the well-designed presentation of interesting data—a matter of substance, of statistics, and of design.

Graphical excellence consists of complex ideas communicated with clarity, precision and efficiency.

Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.

Graphical excellence is nearly always multivariate.

Graphical excellence requires telling the truth about the data.

Data graphics should complement what humans do well.

“We thrive in information-thick worlds because of our marvelous and everyday capacities to select, edit, single out, structure, highlight, group, pair, merge, harmonize, synthesize, focus, organize, condense, reduce, boil down, choose, ...

categorize, catalog, classify, list, abstract,
scan, look into, idealize, isolate,
discriminate, distinguish, screen,
pigeonhole, pick over, sort, integrate,
blend, inspect, filter, lump, skip, smooth,
chunk, average, approximate, cluster, ...

aggregate, outline, summarize, itemize, review, dip into, flip through, browse, glance into, leaf through, skim, refine, enumerate, glean, synopsize, winnow the wheat from the chaff, and separate the sheep from the goats.”

Graphical integrity.

Design aesthetics.

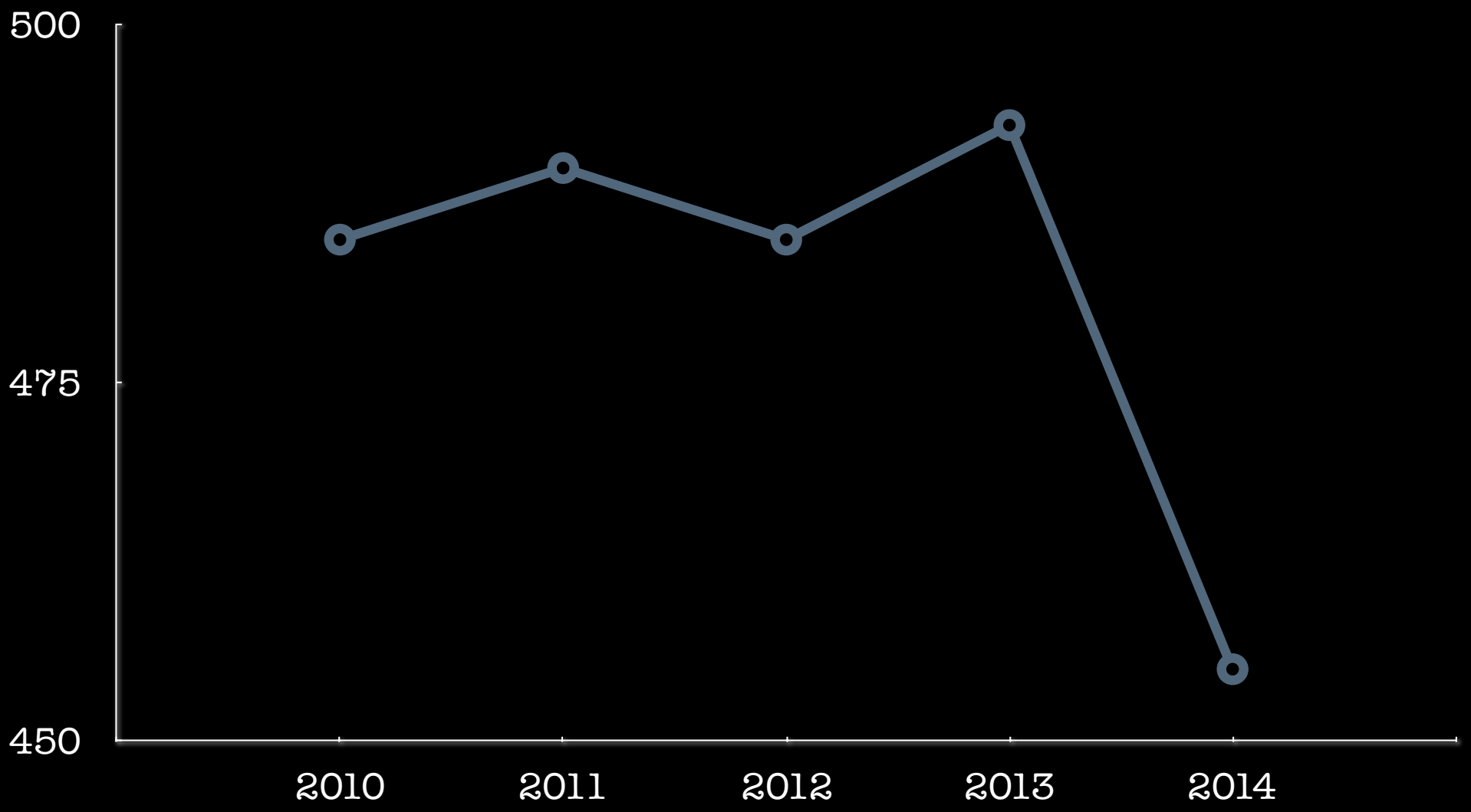
Graphical integrity.

(Tell the truth.)

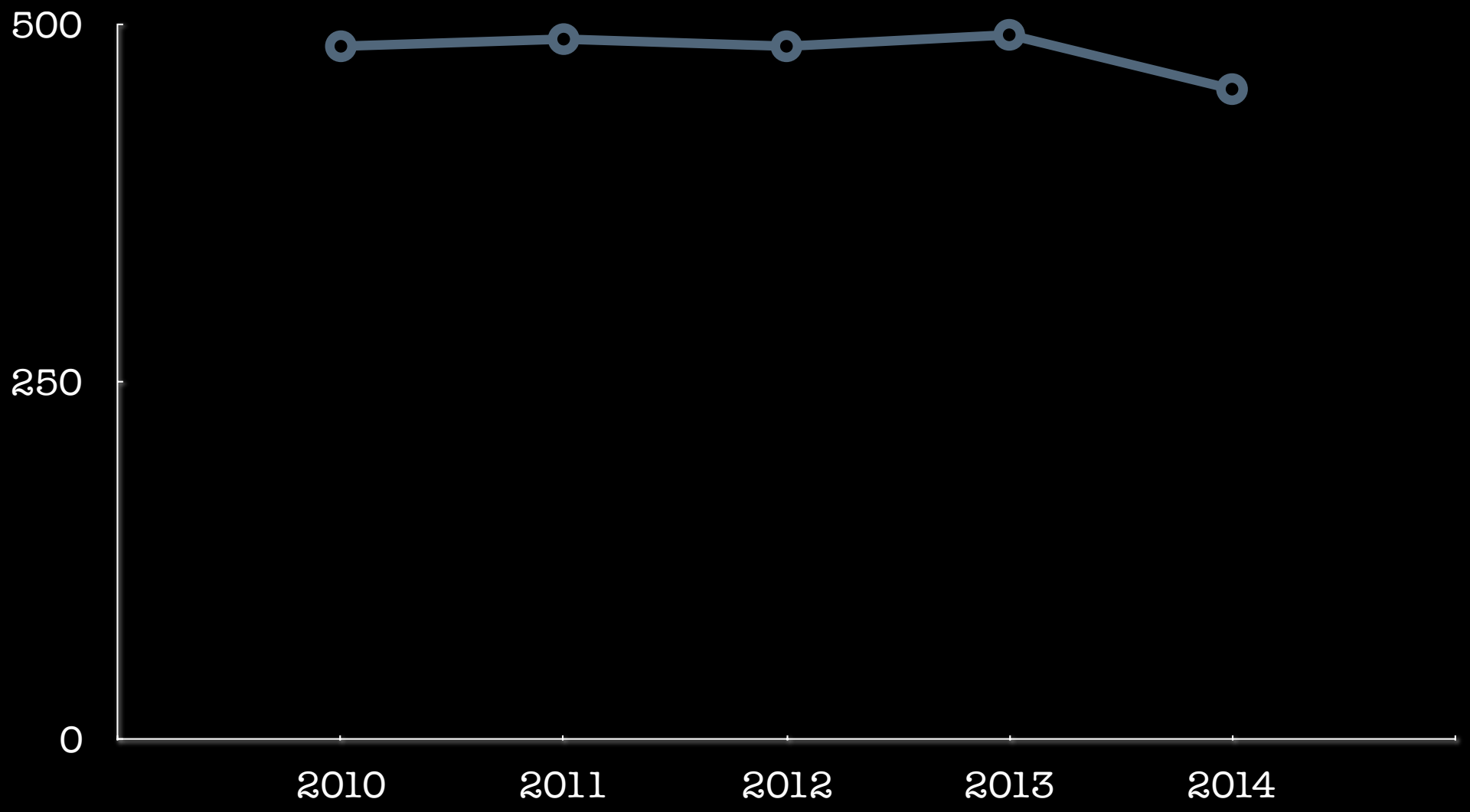
Design aesthetics.

(Do it effectively with clarity & precision.)

Stock market crash?



Show entire scale



Show in context

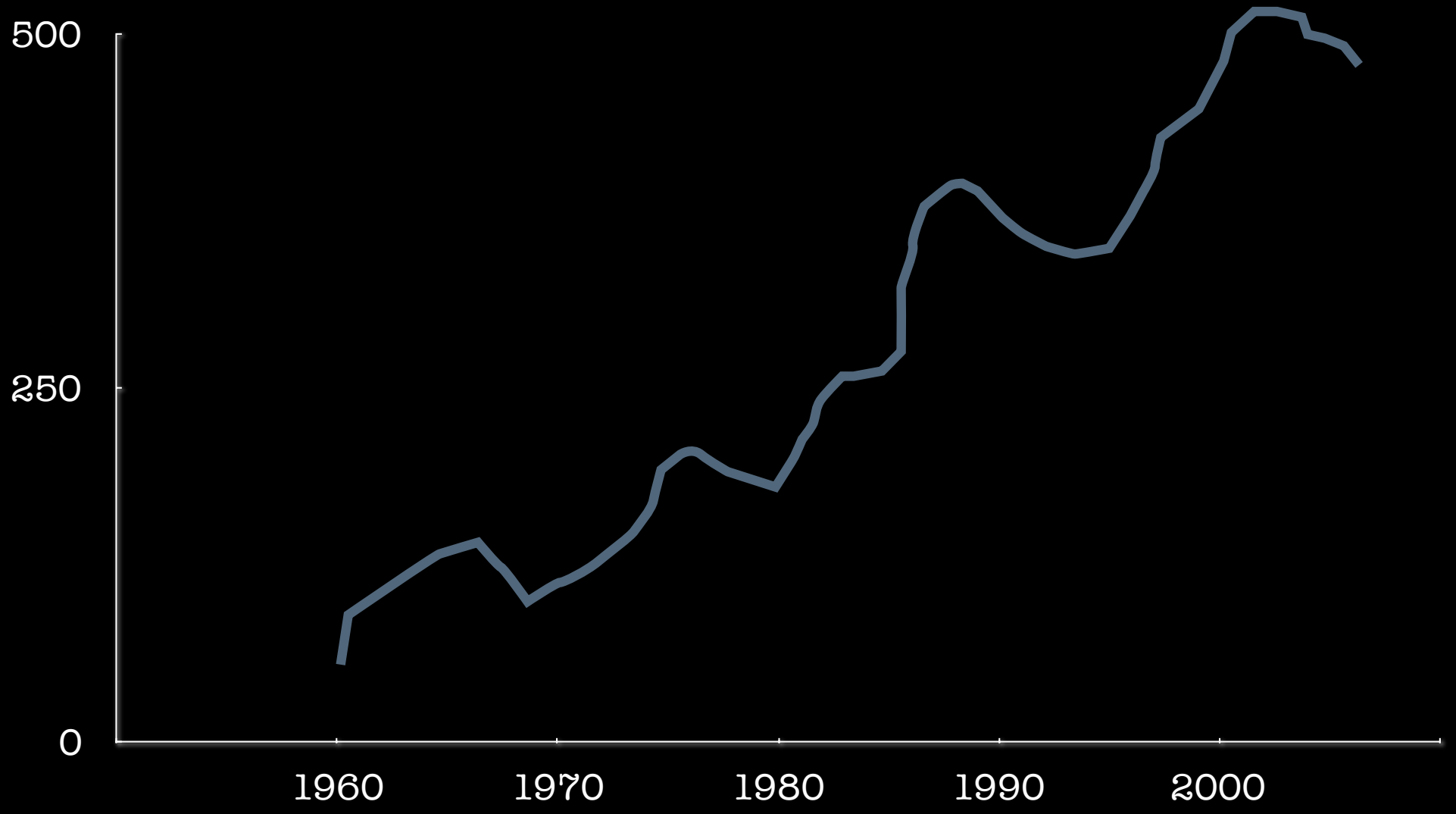
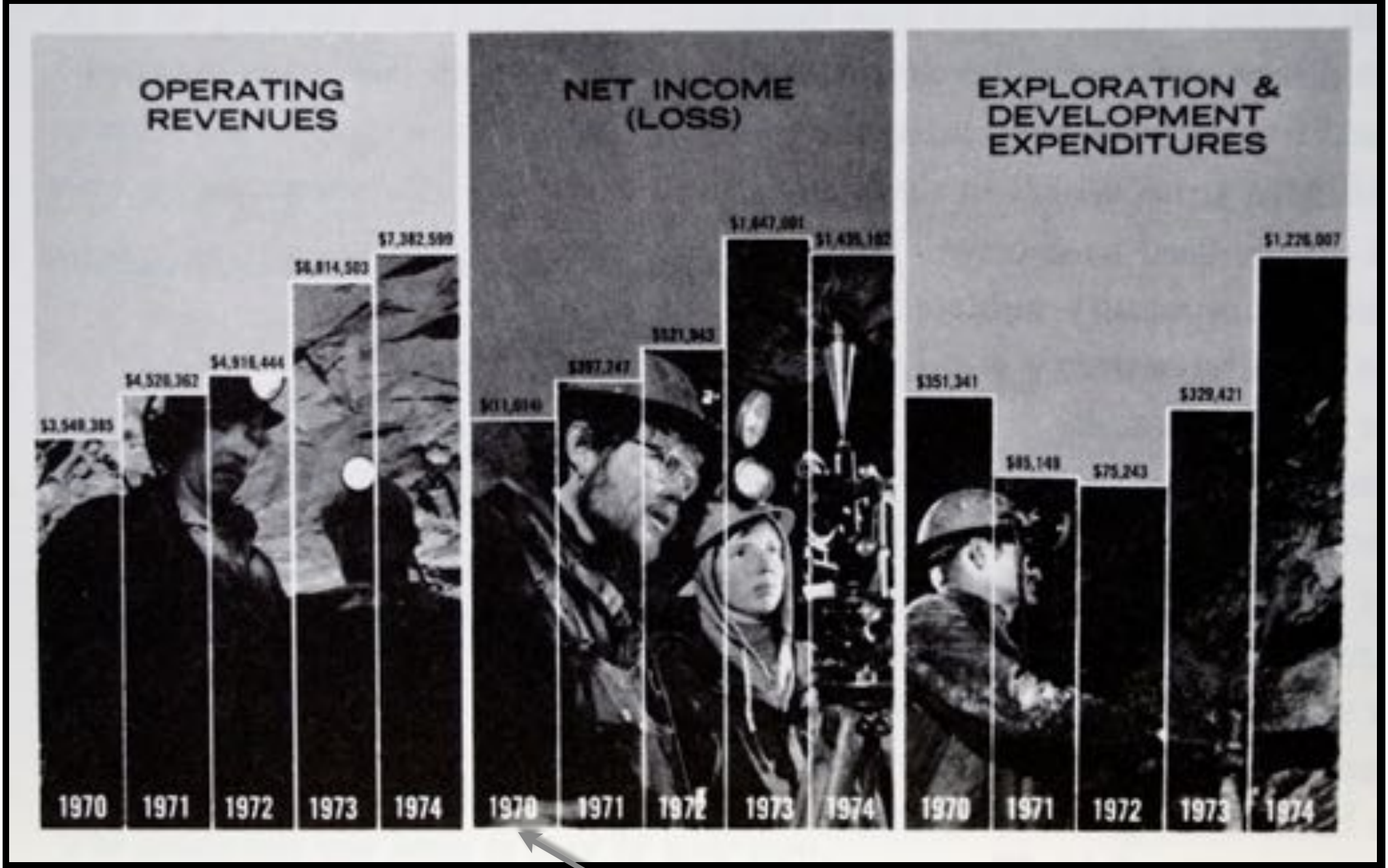


Chart integrity.

Where’s the baseline?

What’s the scale?

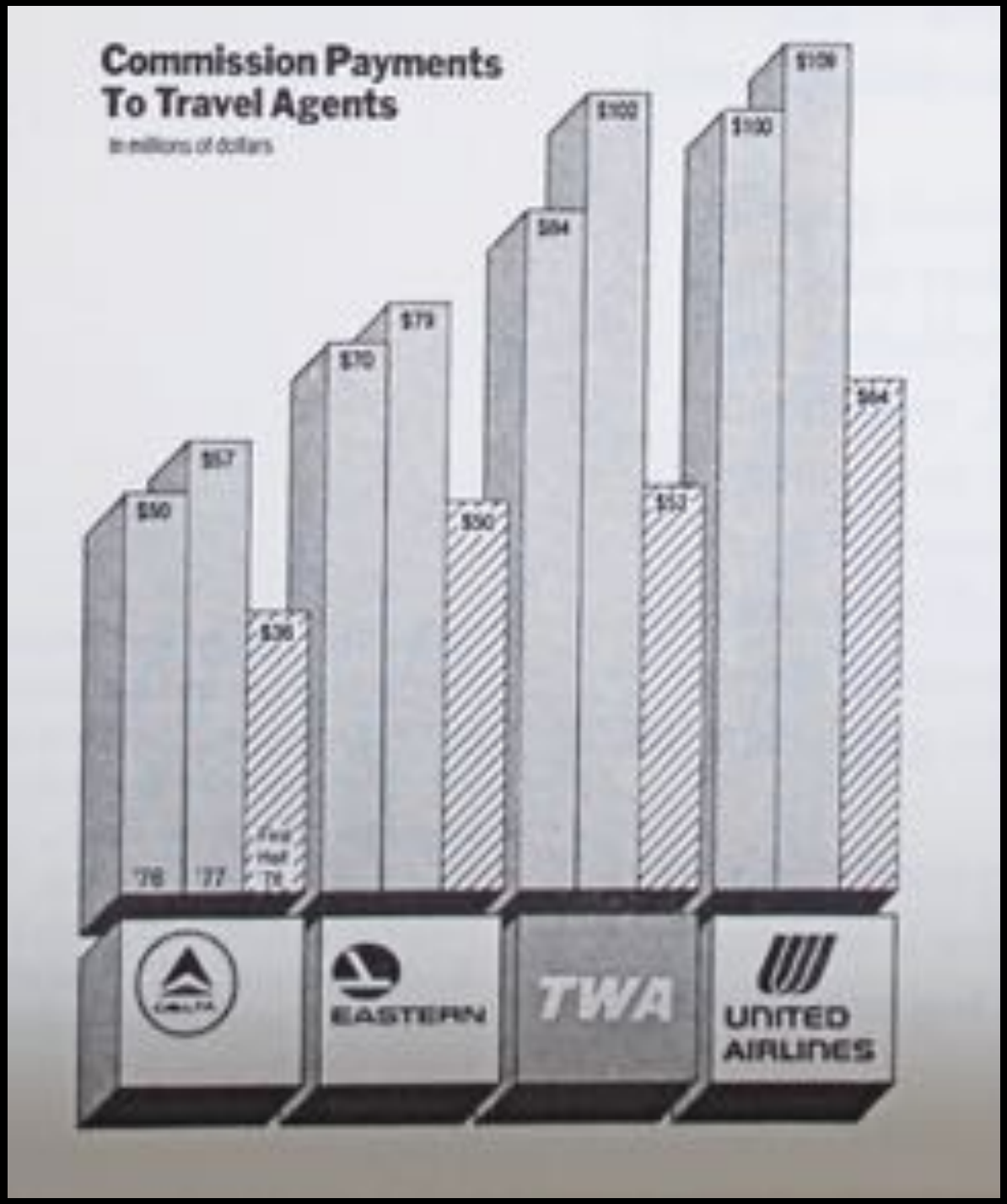
What’s the context?



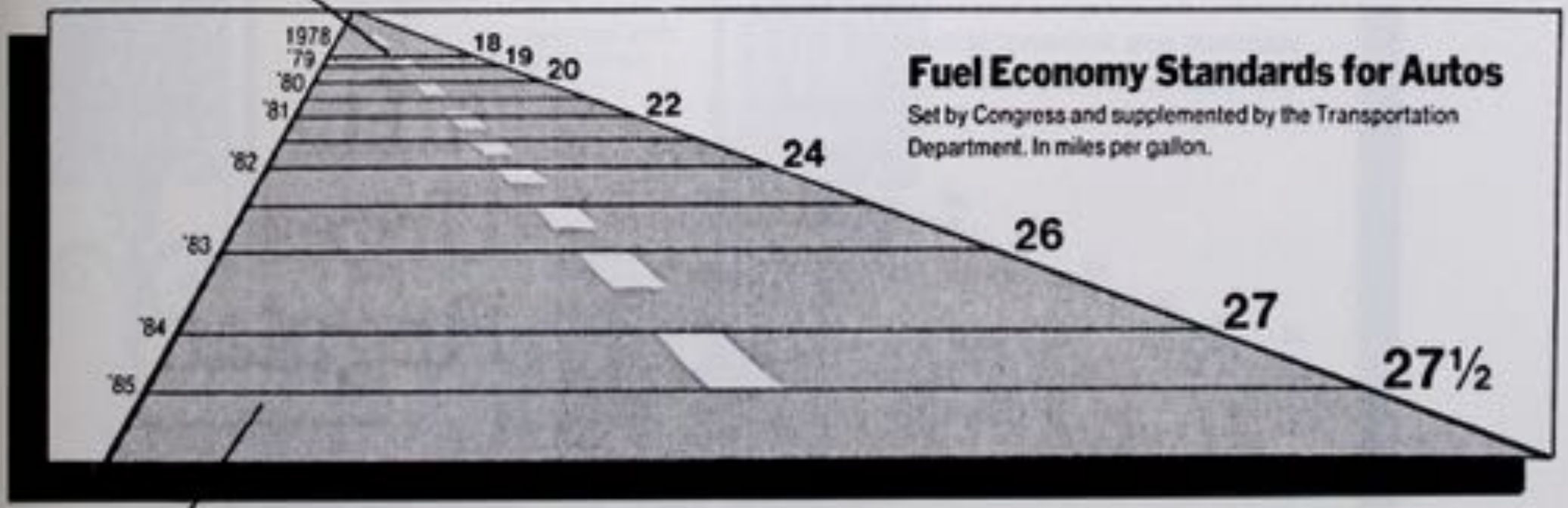
$(4,200,000)

[Vol. 1, p. 54]

What's the component?

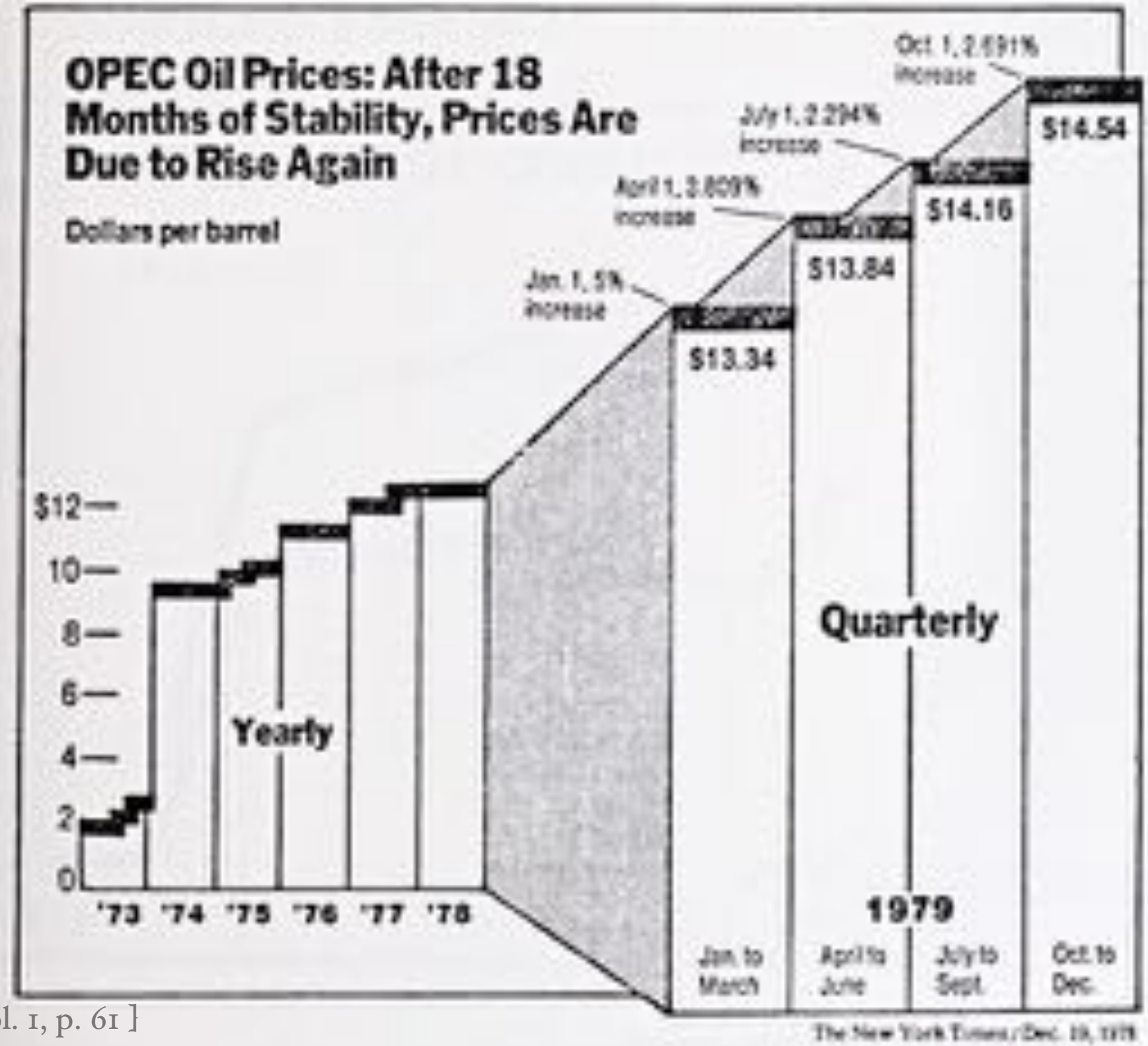


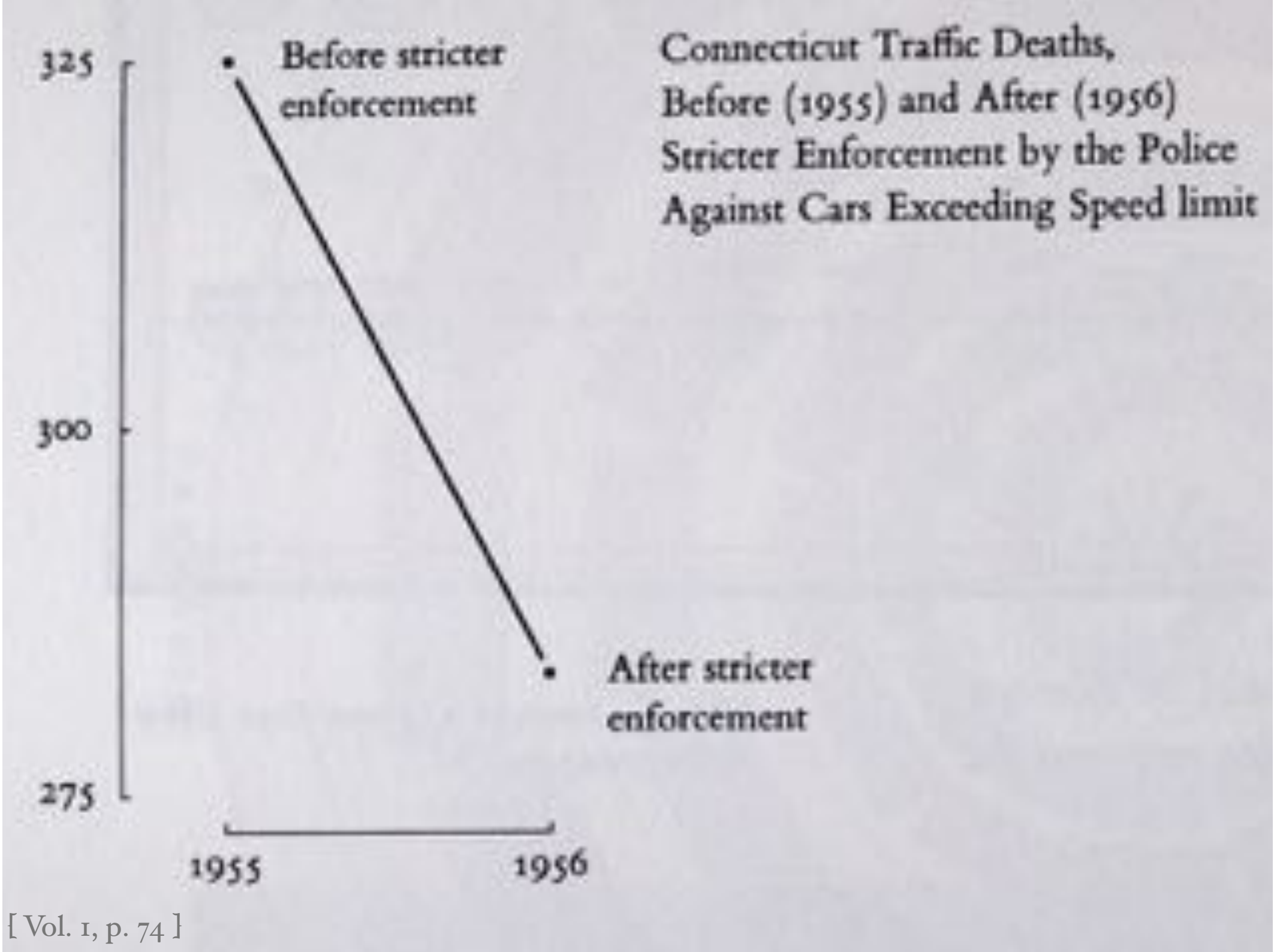
This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



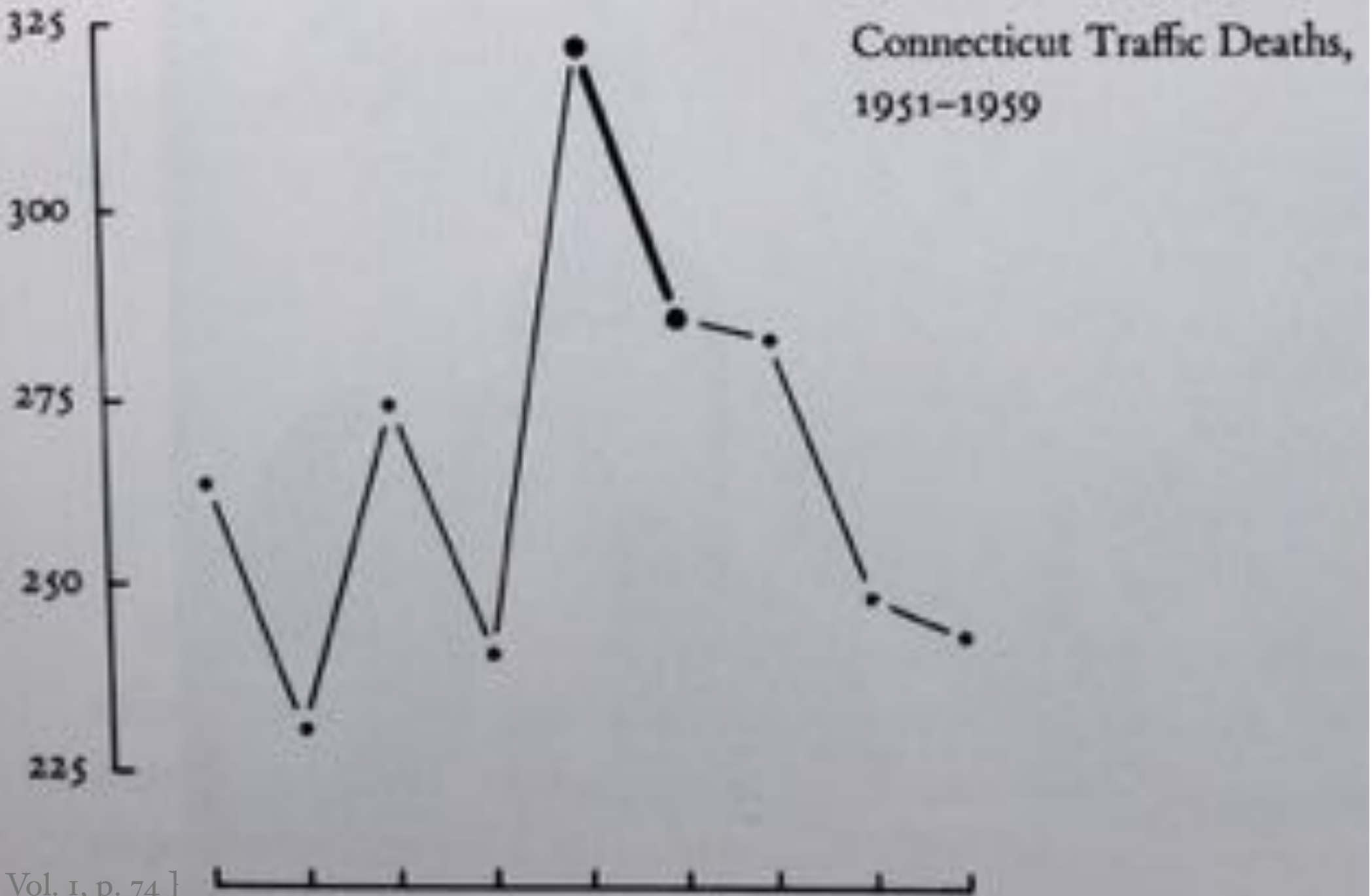
This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

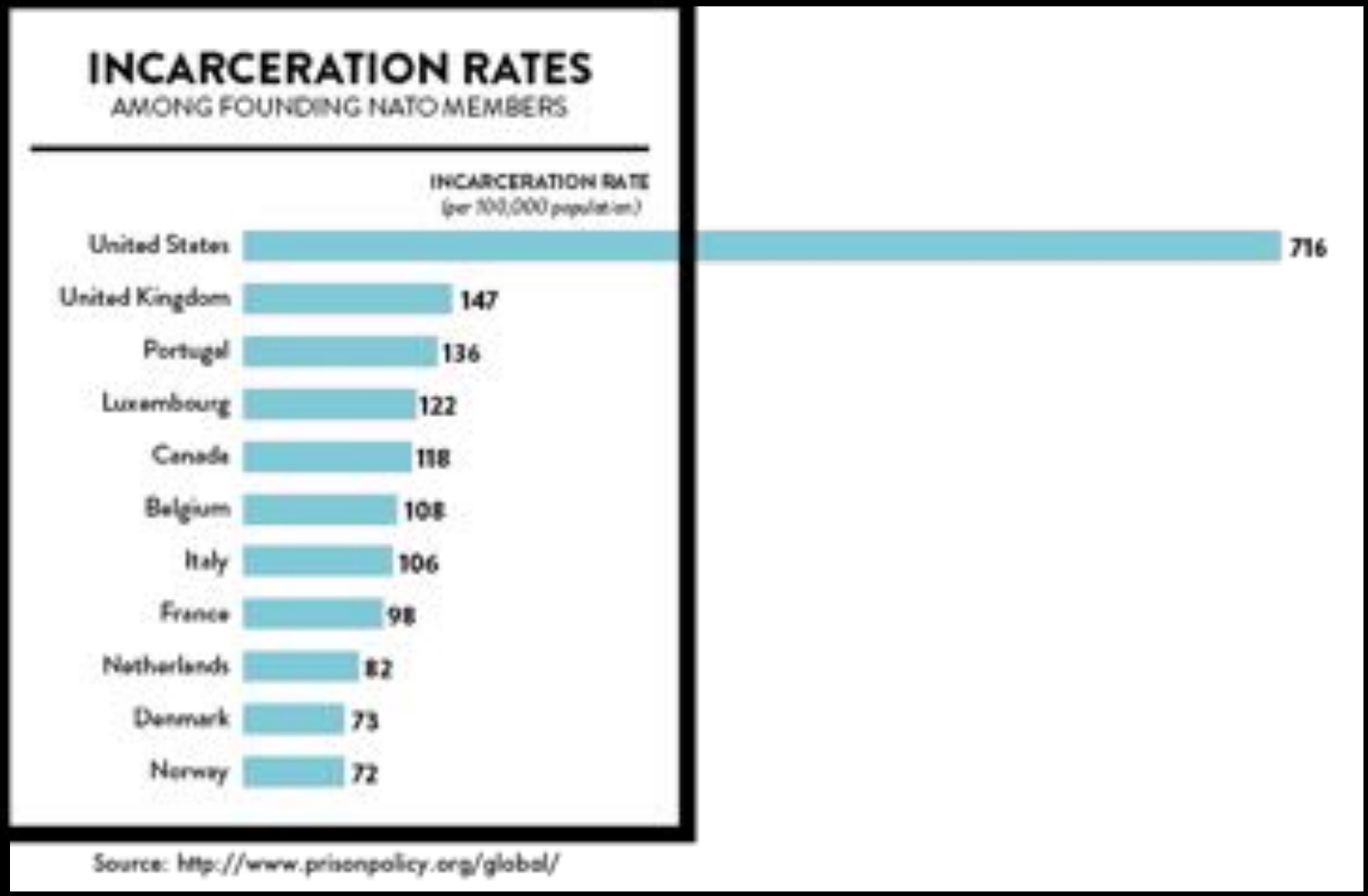
New York Times, August 9, 1978, p. D-2.


OPEC Oil Prices: After 18 Months of Stability, Prices Are Due to Rise Again
Dollars per barrel
$12
10
8
6
4
2
0
'73
'74
'75
'76
'77
'78
Yearly
Jan. 1, 5% increase
April 1, 3.609% increase
July 1, 2.294% increase
Oct. 1, 2.591% increase
$13.34
$13.84
$14.16
$14.54
Quarterly
1979
Jan. to March
April to June
July to Sept.
Oct. to Dec.
The New York Times / Dec. 19, 1978


Connecticut Traffic Deaths,
Before (1955) and After (1956)
Stricter Enforcement by the Police
Against Cars Exceeding Speed limit
325
300
275
Before stricter enforcement
After stricter enforcement
1955
1956

A few more data points add immensely to the account:



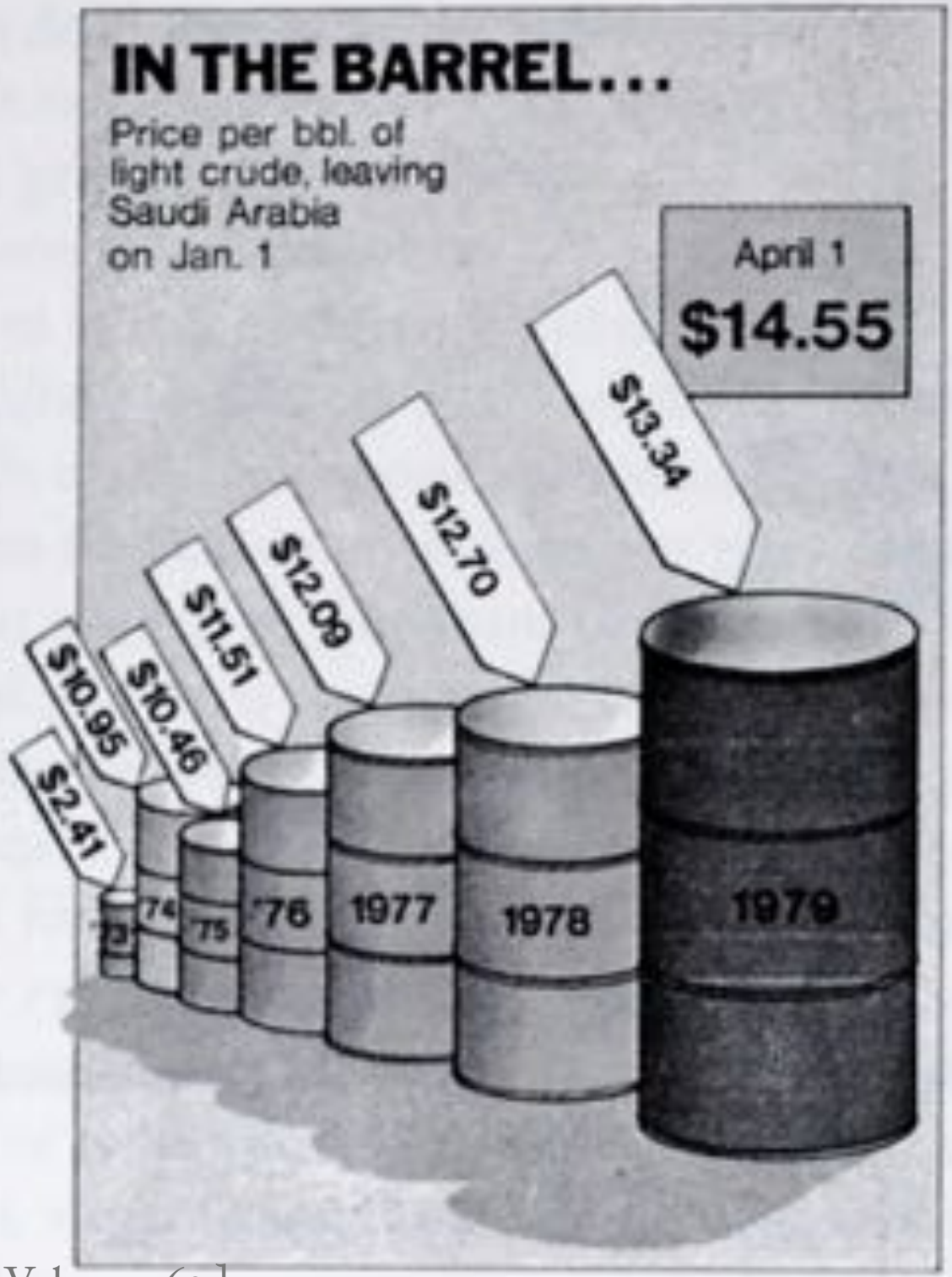

INCARCERATION RATES
AMONG FOUNDING NATO MEMBERS
INCARCERATION RATE
(per 100,000 population)
United States
716
United Kingdom
147
Portugal
136
Luxembourg
122
Canada
118
Belgium
108
Italy
106
France
98
Netherlands
82
Denmark
73
Norway
72
Source: http://www.prisonpolicy.org/global/

Watch size coding.

(height/width)
(area/volume)


Accroissement de nos exportations d'autos 1927-1929
1.969
2.352
2.246
1.934
2.585
2.629
1.643
1.894
2.632
6.646
8.217
11.610
Indochine
Maroc
Tunisie
Algérie

[Vol. 1, p. 69]



Time, April 9, 1979, p. 57.

Measuring Misrepresentation

- Visual attribute value should be directly proportional to data attribute value

$$\text{Lie factor} = \frac{\text{size of effect shown in graphic}}{\text{size of effect shown in data}}$$

$$9.4 = \frac{4280}{454}$$

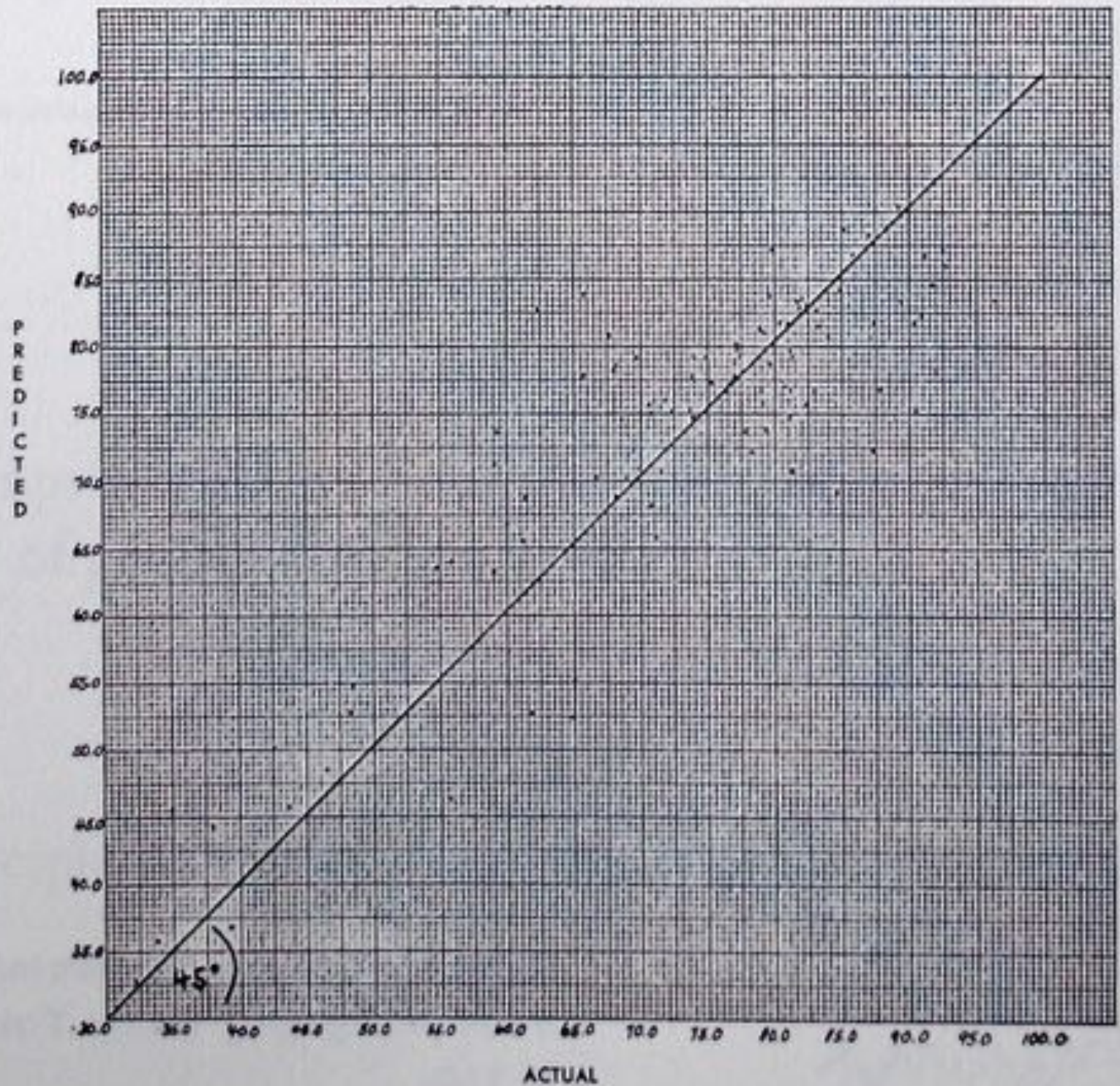
Design aesthetics

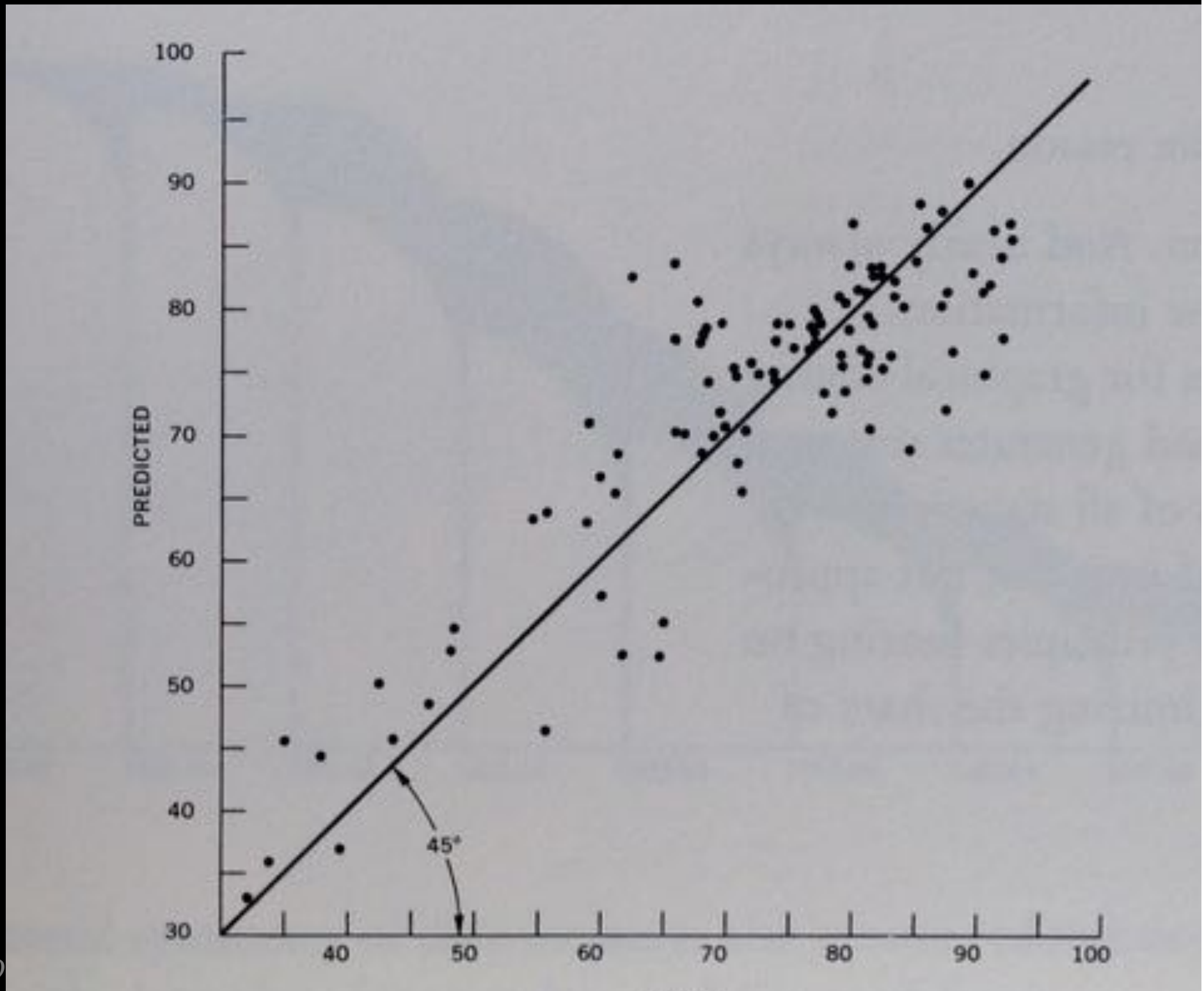
Set of principles to help guide designers.

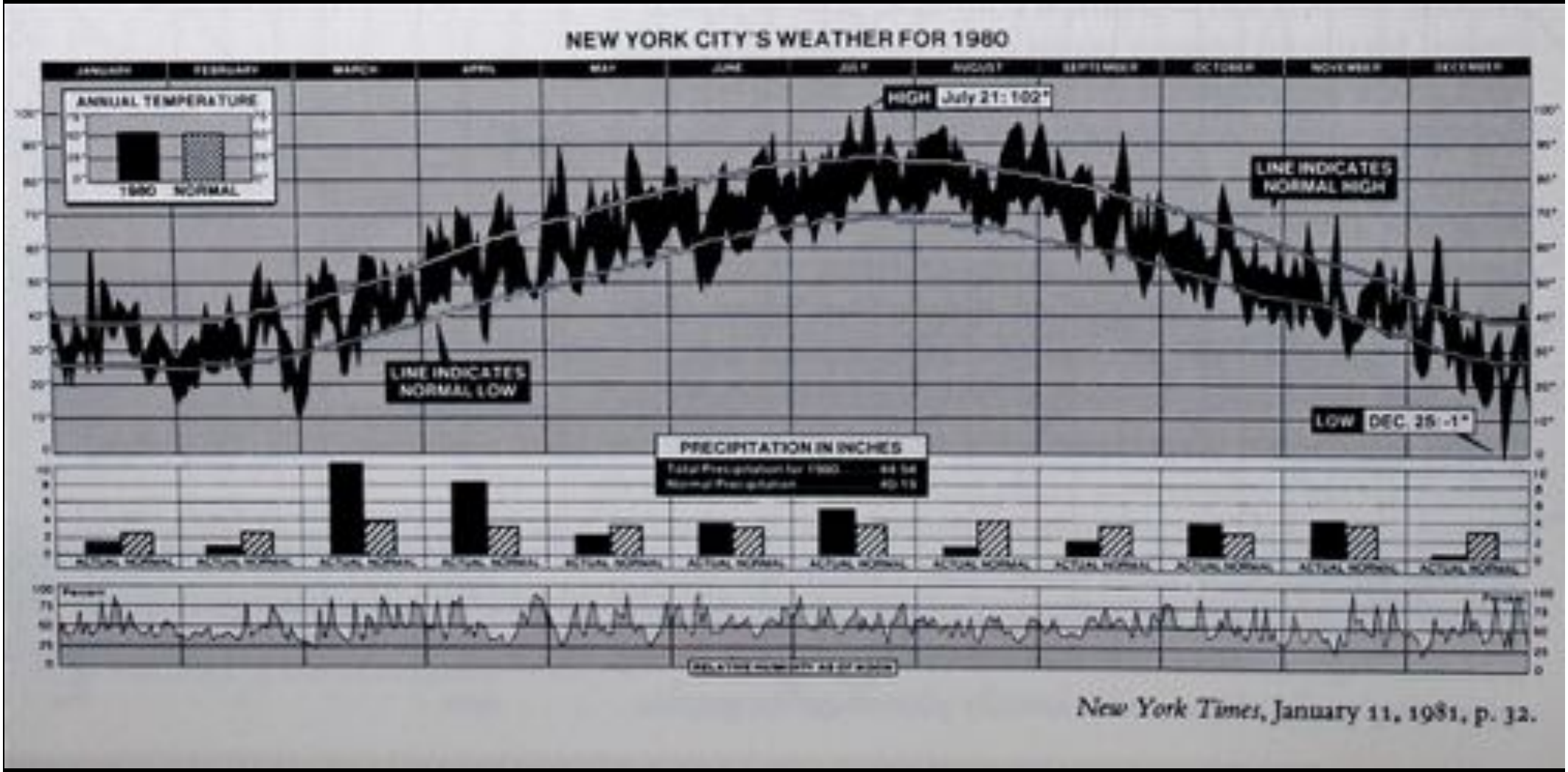
Maximize data ink ratio.

$$\text{data ink ratio} = \frac{\text{data ink}}{\text{total ink used in graphic}}$$

Relationship of Actual Rates of Registration to Predicted Rates
(104 cities 1960).




100
90
80
70
60
50
40
30
PREDICTED
45°
40
50
60
70
80
90
100



New York Times, January 11, 1981, p. 32.

Above all else, show the data.

Maximize data ink ratio.

(Erase non-data ink.)

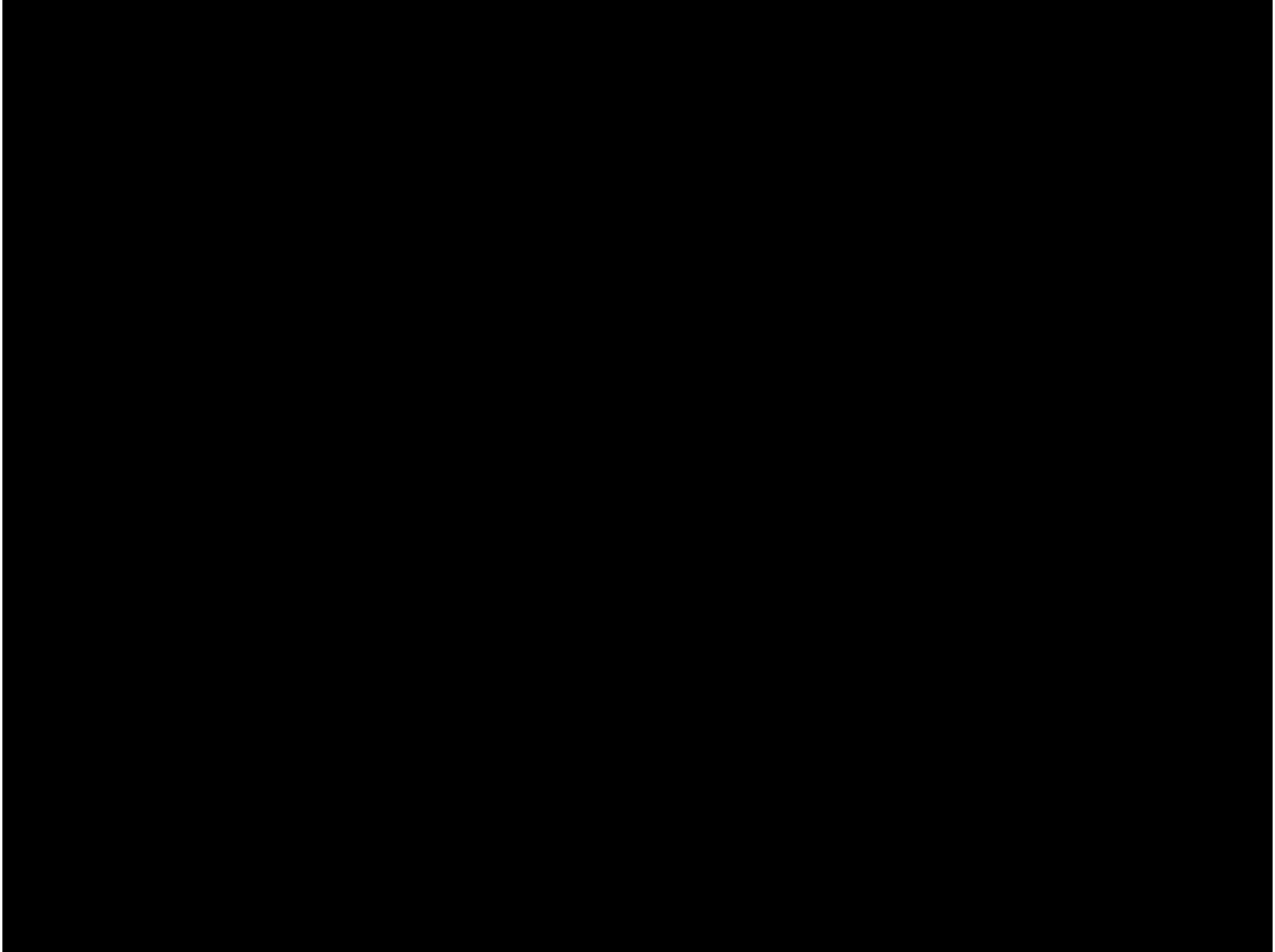
(Erase redundant data ink.)

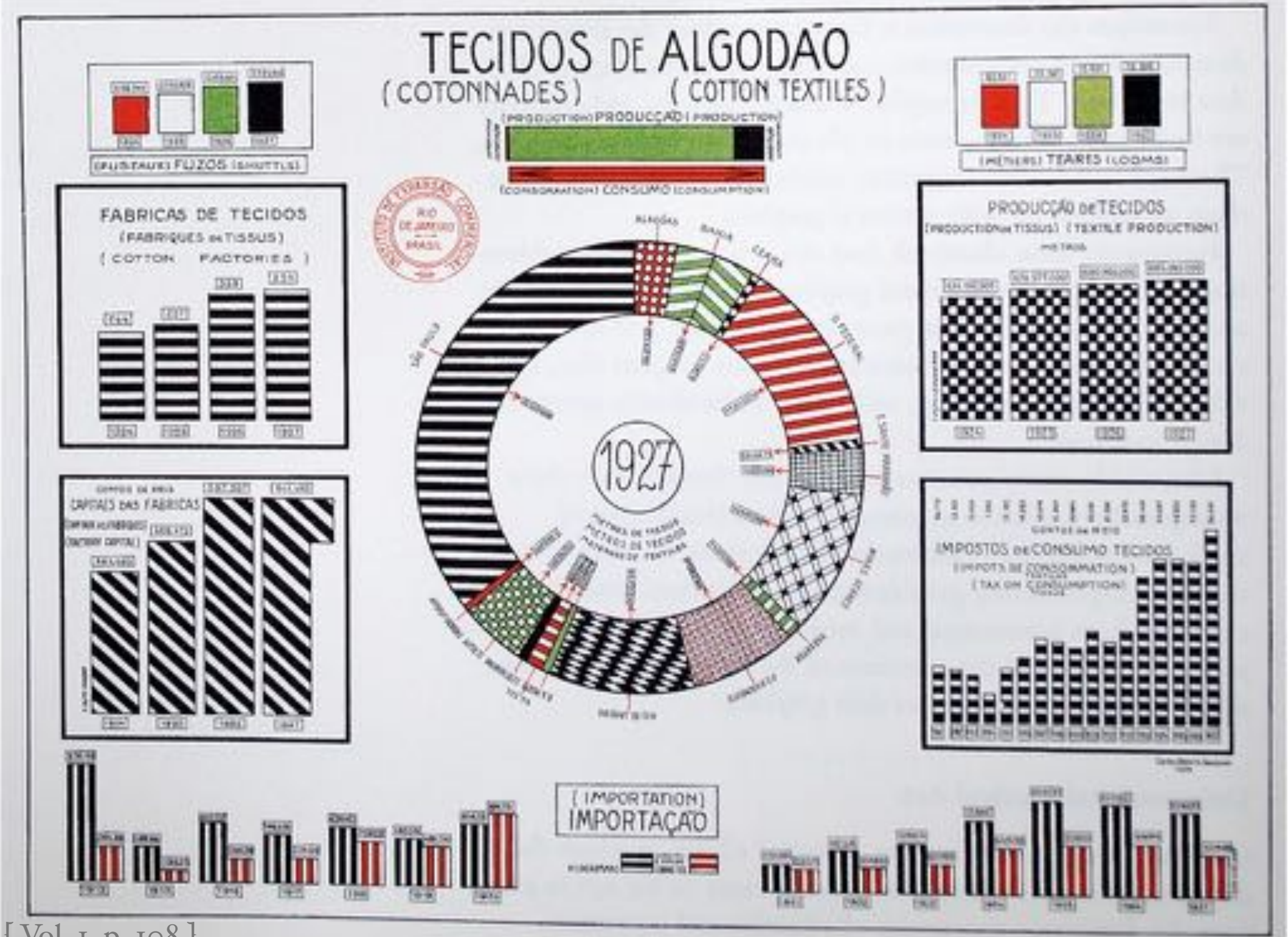
Maximize data density.

$$\text{data density} = \frac{\text{number of data entries}}{\text{area of data graphic}}$$

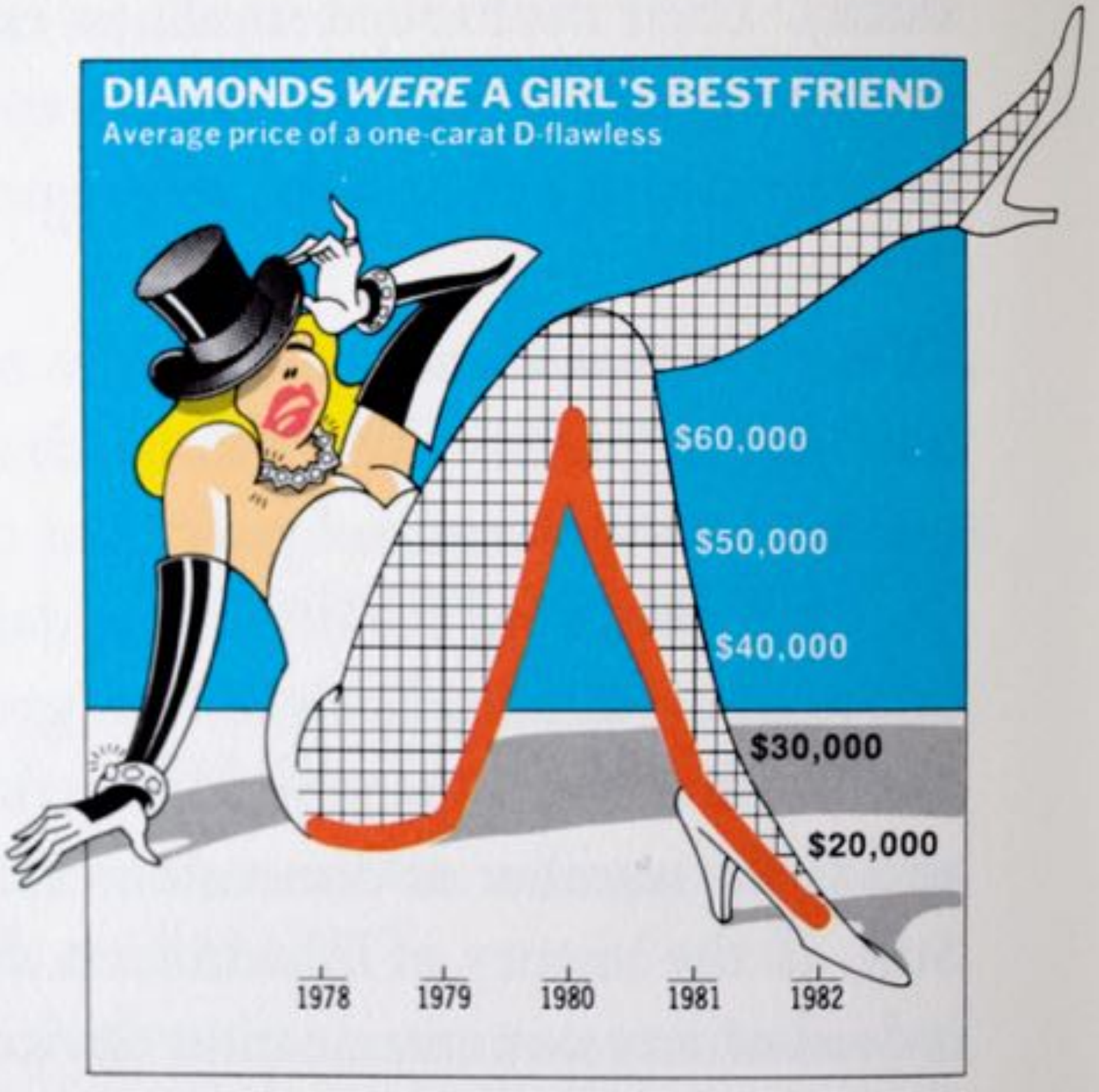
“Maximize data density and the size of the data matrix, within reason.”

[Vol. 1, p. 168]




TECIDOS DE ALGODÃO
(COTONNADES) (COTTON TEXTILES)
(PRODUCTION) PRODUCÇÃO (PRODUCTION)
(CONSOMMATION) CONSUMO (CONSUMPTION)
(NAVETTES) FUZOS (SHUTTLES)
(METIERS) TEARES (LOOMS)
FABRICAS DE TECIDOS
(FABRIQUES de TISSUS)
(COTTON FACTORIES)
PRODUCÇÃO de TECIDOS
(PRODUCTION de TISSUS) (TEXTILE PRODUCTION)
CAPITAES DAS FABRICAS
IMPOSTOS de CONSUMO TECIDOS
(IMPOTS DE CONSOMMATION)
(TAX ON CONSUMPTION)
1927
(IMPORTATION)
IMPORTAÇÃO

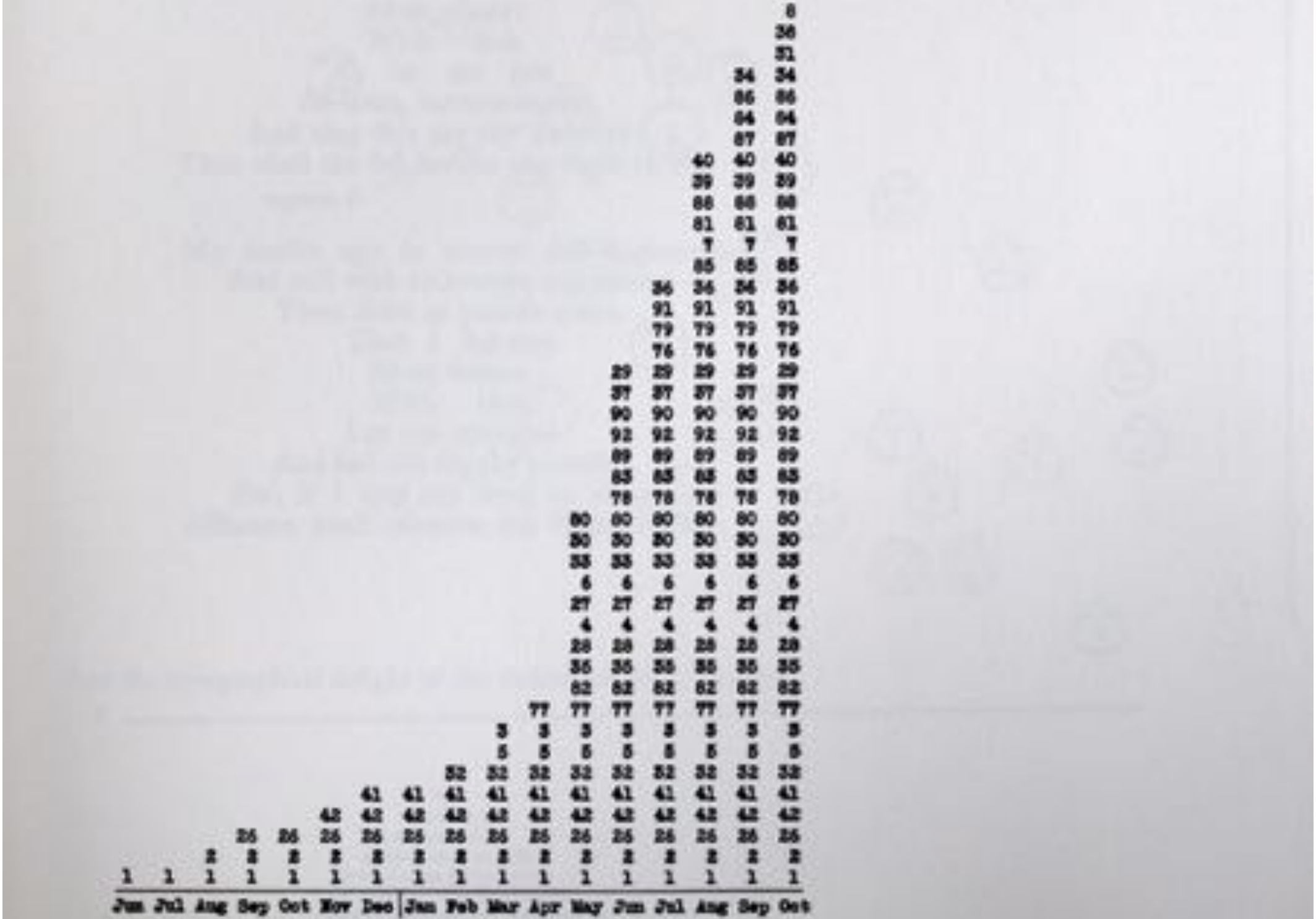
[Vol. 1, p. 108]


DIAMONDS *WERE* A GIRL'S BEST FRIEND
Average price of a one-carat D-flawless
$60,000
$50,000
$40,000
$30,000
$20,000
1978
1979
1980
1981
1982

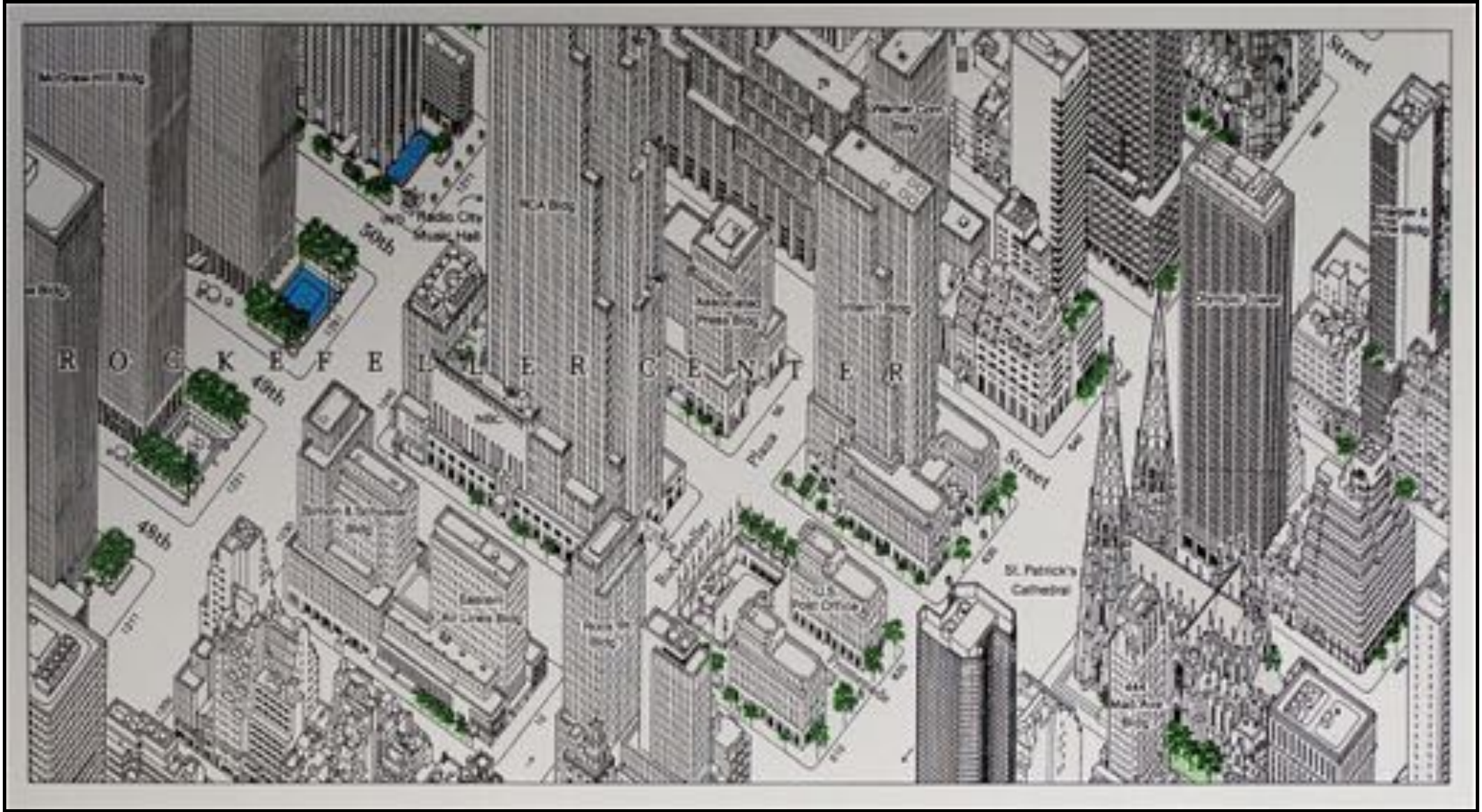

USA Today Snapshots - USATODAY.com
http://www.usatoday.com/news/snapshot.htm
Cars - Auto Financing - Event Tickets - Jobs - Real Estate - Online Degrees - Business Opportunities - Shopping
Search
Home
News
Travel
Money
Sports
Life
Tech
Weather
News
Nation
Politics
Washington
World
Health & Behavior
Opinion
Education
Religion
Barack Obama, 47, would not be the youngest president to take office.
Youngest first-term presidents
Theodore Roosevelt
John F. Kennedy
Bill Clinton
Ulysses S. Grant
Grover Cleveland
42
43
46
46
47
By Anne R. Carey and Alejandro Gonzales, USA TODAY
Source: www.infoplease.com
1/20
News
Sports
Money
Life

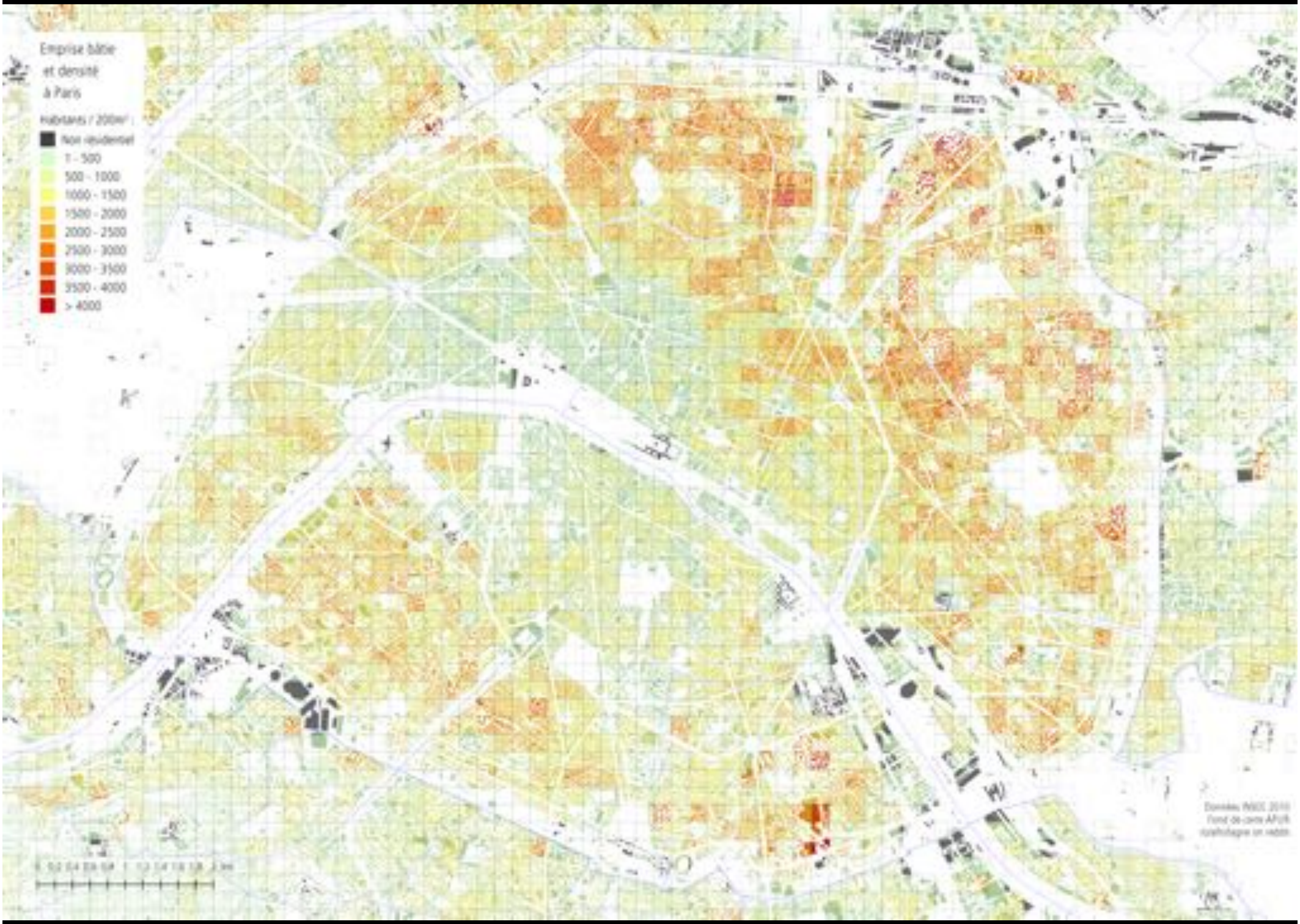
Use multifunctioning graphical elements.

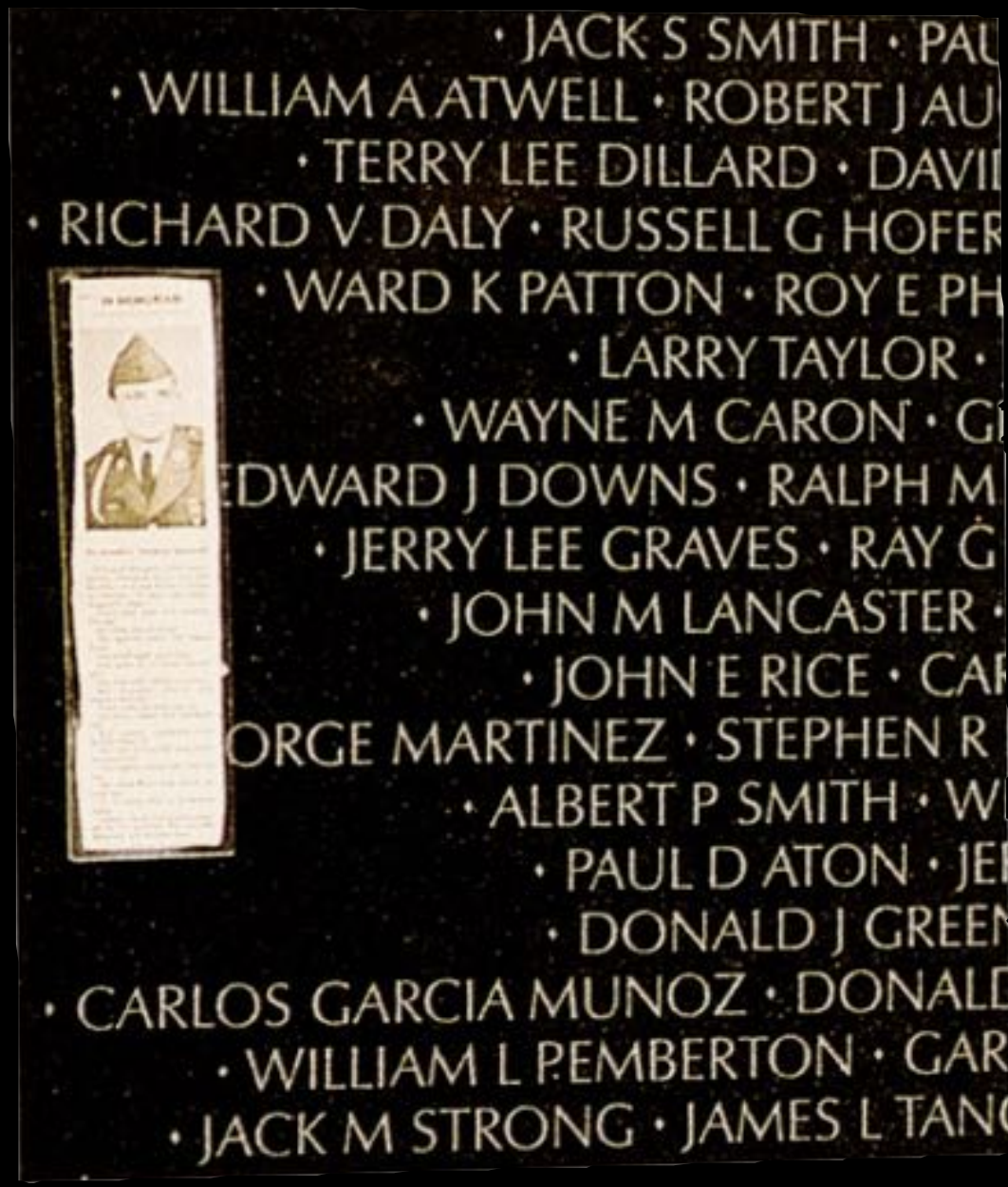
(macro/micro readings)


Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
1917
1918


Pont
neuf

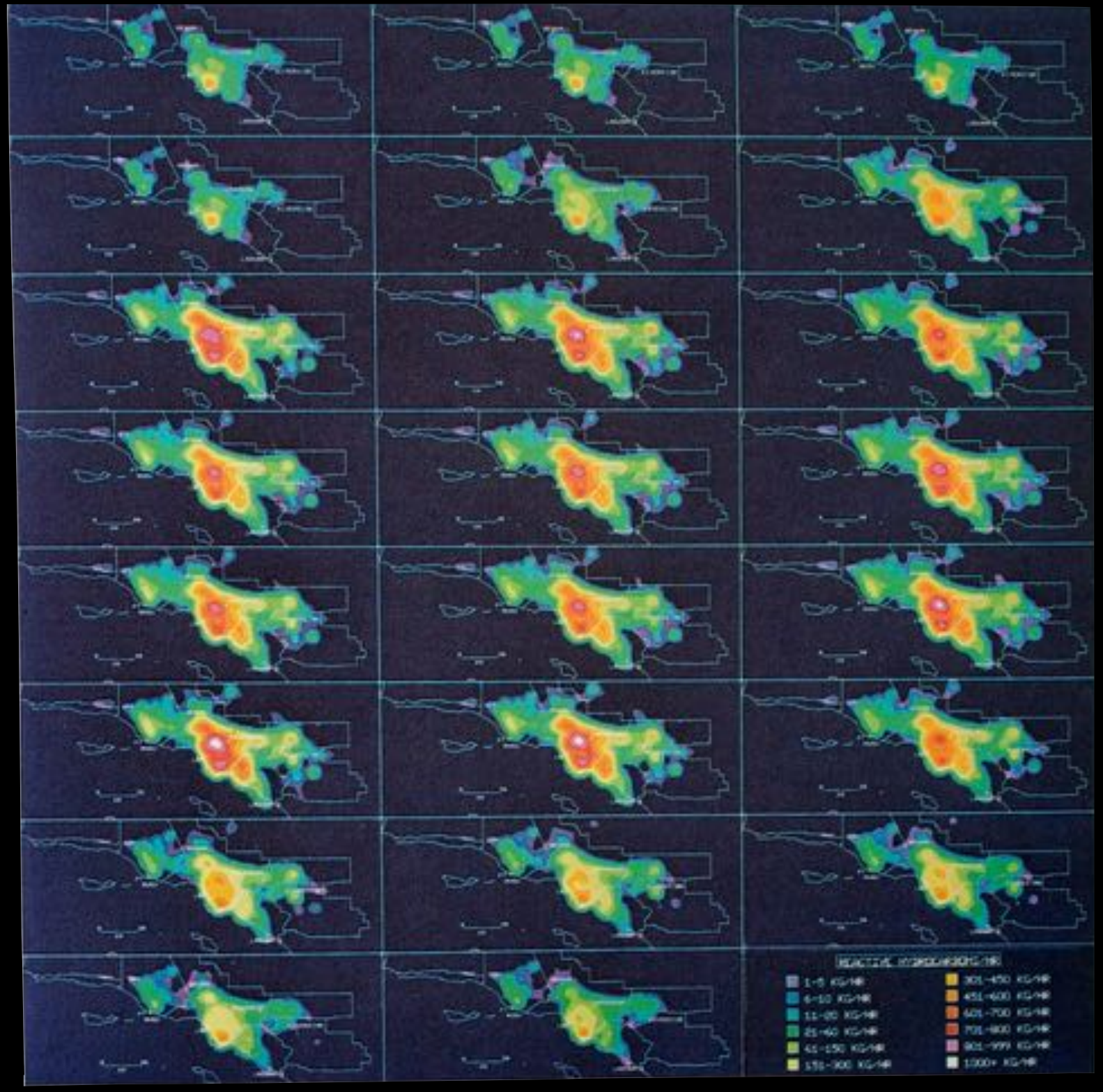

ROCKEFELLER CENTER
RCA Bldg.
Radio City Music Hall
50th
49th
49th
Street
Street
St. Patrick's Cathedral
U.S. Post Offices


Emprise bâtie
et densité
à Paris
Habitants / 200m²
Non résidentiel
1 - 500
500 - 1000
1000 - 1500
1500 - 2000
2000 - 2500
2500 - 3000
3000 - 3500
3500 - 4000
> 4000

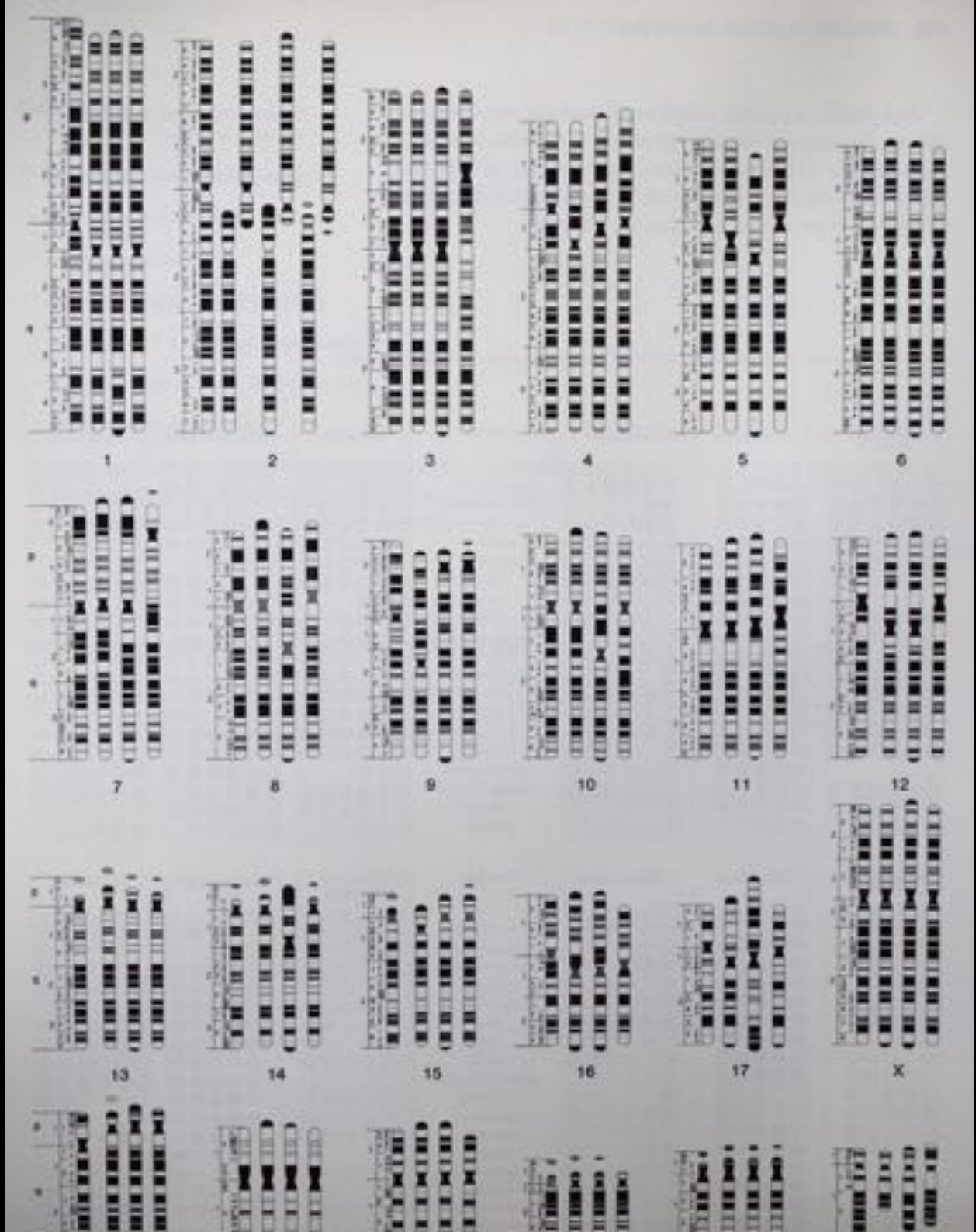

· JACK S SMITH · PAU
· WILLIAM A ATWELL · ROBERT J AU
· TERRY LEE DILLARD · DAVI
· RICHARD V DALY · RUSSELL G HOFER
· WARD K PATTON · ROY E PH
· LARRY TAYLOR ·
· WAYNE M CARON · G
EDWARD J DOWNS · RALPH M
· JERRY LEE GRAVES · RAY G
· JOHN M LANCASTER ·
· JOHN E RICE · CA
ORGE MARTINEZ · STEPHEN R
· ALBERT P SMITH · W
· PAUL D ATON · JE
· DONALD J GREE
· CARLOS GARCIA MUNOZ · DONALD
· WILLIAM L PEMBERTON · GAR
· JACK M STRONG · JAMES L TAN

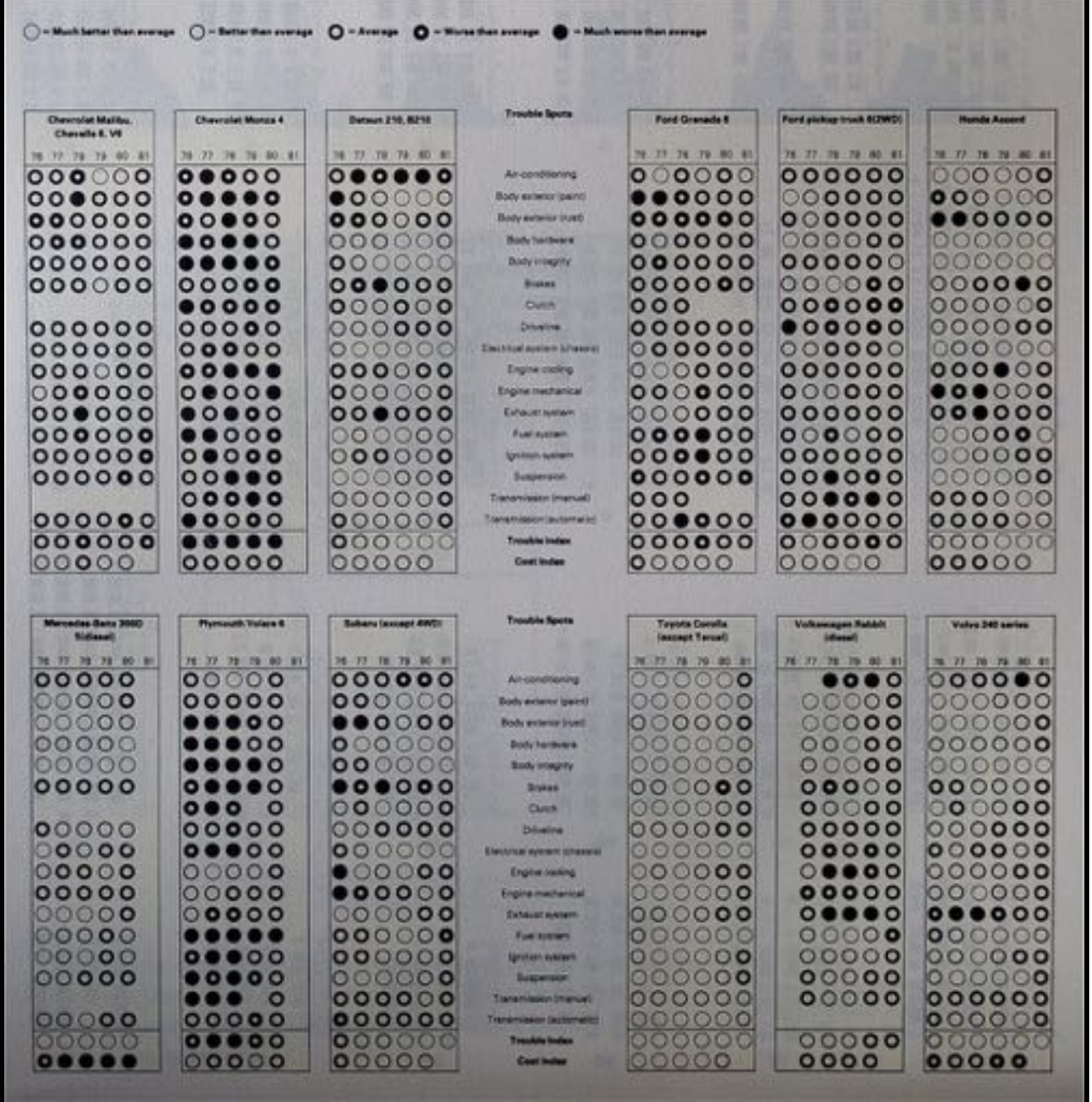

ANDREW M HUD
THOMAS A GIUD · DELBERT
KENNETH F OLENZUK · HUGHIE OXEN
PHILLIP E NEFF · JERRY A SELLERS · JOE T SHU
RAYMOND S ADAMS · LANCE B BARTON · M
WILLIAM H CAMPBELL III · JOSEPH T CLARK ·
ALLEN D FORD · JAMES H GAMBLE · DARREL
BARRY S KYLE · DARYL LEE LIGONS · MATTHE
STEPHEN M VUGA · MICHAEL R RICE · GERA
ROBERT A SIKON · THOMAS M VAN ZANDT ·
JOHN E ADDISON · BRUCE C ALFRED · RON
DONALD L APPLEGATE · JOHN R ARRINGTO
CALVIN W BILES · JOHN P BARSCH · DAVID
WILLIAM H CARPENTER Jr · WILLIAM A CAS
WILLIAM R CRITCHFIELD · DONALD J CRUD
MICHAEL D FULLER · GARRY L GABRIEL · FRA
ROGER L HENSON · ROBERT E HENTSCHEL ·
THOMAS S HUBBELL · MITCHELL HUGHES Jr
NORMAN W CLEARWATER · MICHAEL L ION
RONALD F KITZKE · DAN T KLINDT · IRVIL E
EARL L LEWIS · RICHARD E LEWIS · VERNON
CARLOS J M LOZANO · ARPHALIA L RICHAR
JOHNSON MINNITEE Jr · MICHAEL J MINOR
CHARLES D POPE · VERNON B RAINS · ST EL
THOMAS W MALLOY · ROBERT T RIDDLE · A
DENNIS L SCOTT · STEVEN E SHEKELL · DAR
ROBERT M THOMPSON · THOMAS A
STEPHEN WILLIAMS · KENNETH
RONALD C BRESHEARS
DANIEL L HAWENS
PHILIP N CAN

Use small multiples.



[Vol. 1, p. 170]


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
X


○ = Much better than average
○ = Better than average
○ = Average
○ = Worse than average
● = Much worse than average
Chevrolet Malibu, Chevelle 8, V8
Chevrolet Monza 4
Datsun 210, B210
Trouble Spots
Ford Granada 8
Ford pickup truck 6(2WD)
Honda Accord
76 77 78 79 80 81
Air-conditioning
Body exterior (paint)
Body exterior (rust)
Body hardware
Body integrity
Brakes
Clutch
Driveline
Electrical system (chassis)
Engine cooling
Engine mechanical
Exhaust system
Fuel system
Ignition system
Suspension
Transmission (manual)
Transmission (automatic)
Trouble Index
Cost Index
Mercedes-Benz 300D 5(diesel)
Plymouth Volare 6
Subaru (except 4WD)
Trouble Spots
Toyota Corolla (except Tercel)
Volkswagen Rabbit (diesel)
Volvo 240 series
76 77 78 79 80 81
Air-conditioning
Body exterior (paint)
Body exterior (rust)
Body hardware
Body integrity
Brakes
Clutch
Driveline
Electrical system (chassis)
Engine cooling
Engine mechanical
Exhaust system
Fuel system
Ignition system
Suspension
Transmission (manual)
Transmission (automatic)
Trouble Index
Cost Index

FORWARD END OF
LOCAL TRAIN
HOBOKEN-HUDSON TERM.

FORWARD END OF
EXPRESS TRAIN
HOBOKEN-HUDSON TERM.

FORWARD END OF TRAIN
HOBOKEN-33RD ST.

FORWARD END OF
LOCAL TRAIN
SUMMIT AVE.-HUDSON TERM.

FORWARD END OF
EXPRESS TRAIN
SUMMIT AVE.-HUDSON TERM.

FORWARD END OF TRAIN
SUMMIT AVE.-33RD ST.

FORWARD END OF TRAIN
PARK PLACE
HUDSON TERM.

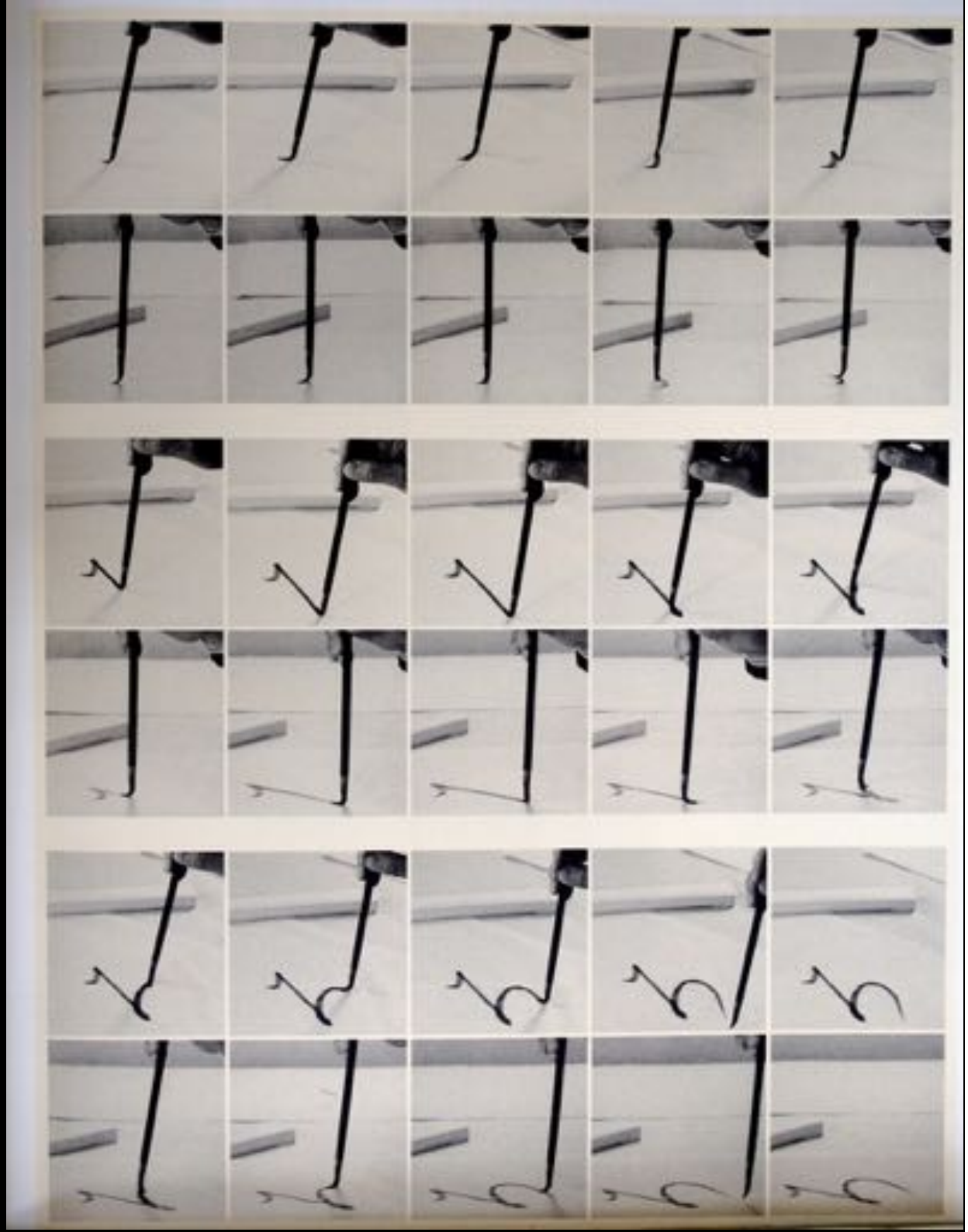
FORWARD END OF TRAIN
MANHATTAN TRANSFER-
HUDSON TERM.

FORWARD END OF TRAIN
33RD ST.-HUDSON TERM.

FORWARD END OF LIGHT TRAIN
(ONE BOX LAMP ONLY
ON RAPID TRANSIT DIVISION)

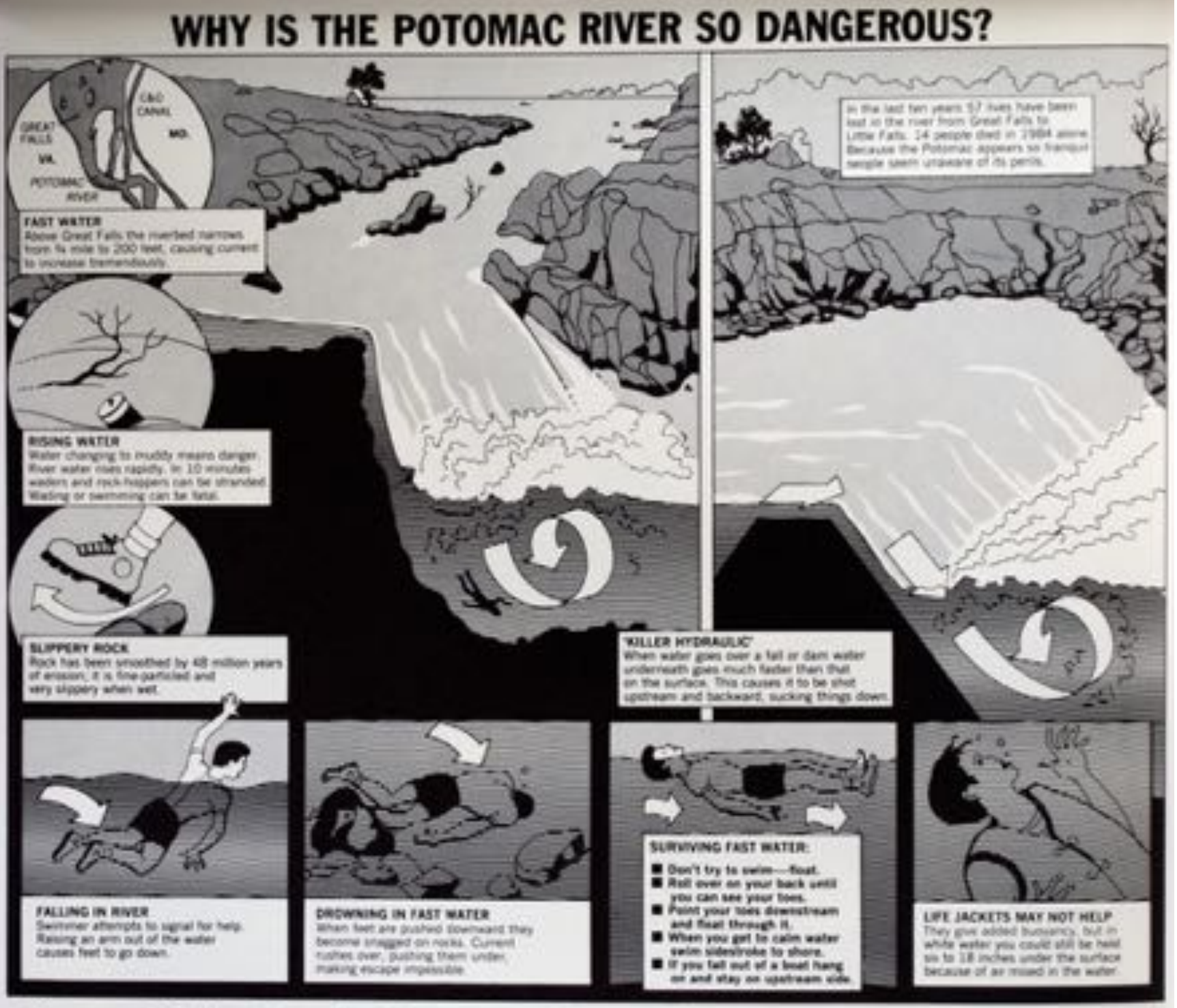
FORWARD END OF TRAIN
GROVE ST.-33RD ST.

REAR END OF TRAIN
(ONE BOX LAMP ONLY
ON RAPID TRANSIT DIVISION)

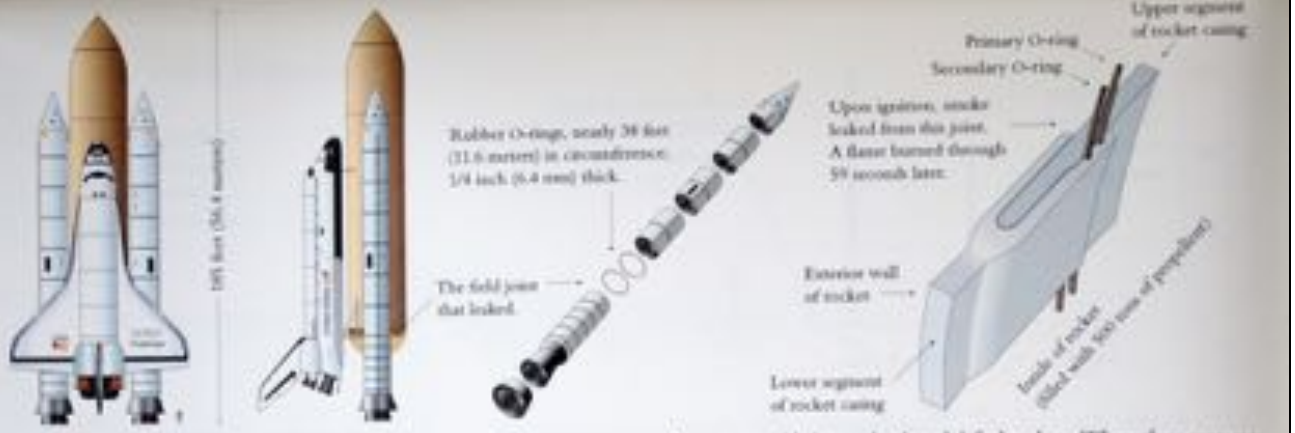


Show mechanism, process, dynamics,
and causality.

(cause & effect are key)



Great Falls Park Rangers Pray for Rain, to Save Lives



The shuttle consists of an *orbiter* (which carries the crew and has powerful engines in the back), a large liquid-fuel tank for the orbiter engines, and 2 solid-fuel *booster* rockets mounted on the sides of the central tank. Segments of the booster rockets are shipped to the launch site, where they are assembled to make the solid-fuel rockets. Where these segments mate, each joint is sealed by two rubber O-rings as shown above. In the case of the Challenger accident, one of these joints leaked, and a torch-like flame burned through the side of the booster rocket.

Less than 1 second after ignition, a puff of smoke appeared at the aft joint of the right booster, indicating that the O-rings burned through and failed to seal. At this point, all was lost.

On the launch pad, the leak lasted only about 2 seconds and then apparently was plugged by putty and insulation as the shuttle rose, flying through rather strong cross-winds. Then 58.788 seconds after ignition, when the Challenger was 6 miles up, a flicker of flame emerged from the leaky joint. Within seconds, the flame grew and engulfed the fuel tank (containing liquid hydrogen and liquid oxygen). That tank ruptured and exploded, destroying the shuttle.

As the shuttle exploded and broke up at approximately 73 seconds after launch, the two booster rockets crisscrossed and continued flying wildly. The right booster, identifiable by its failure plume, is now to the left of its non-defective counterpart.

The flight crew of Challenger 51-L. Front row, left to right: Michael J. Smith, pilot; Francis R. (Dick) Scobee, commander; Ronald E. McNair. Back row: Ellison S. Onizuka, S. Christa McAuliffe, Gregory B. Jarvis, Judith A. Resnik.

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View: Erosion Depth (in.)	Cross Sectional View: Peripheral Affected (deg)	Cross Sectional View: Nominal Dia. (in.)	Top View: Length Of Max Erosion (in.)	Top View: Total Heat Affected Length (in.)	Clocking Location (deg)
61A LH Center Field**	22A	None	None	0.280	None	None	36°-66°
61A LH FORWARD FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
51C LH Forward Field**	15A	0.010	154.8	0.280	4.25	5.25	183
51C RH Center Field (prim)***	15B	0.038	130.8	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.8	0.280	None	29.50	354
41B RH Forward Field	13B	0.028	113.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.048	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.3	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

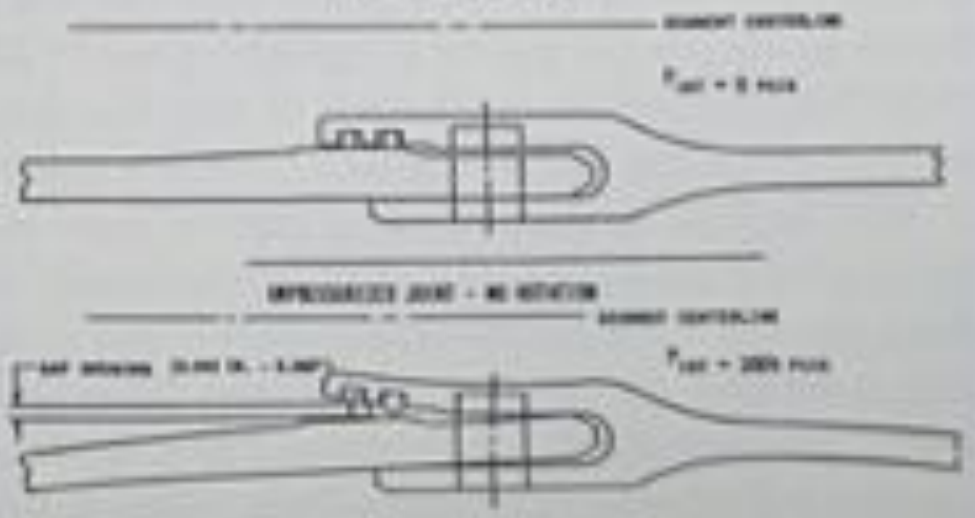
PRIMARY CONCERNS -

FIELD JOINT - HIGHEST CONCERN

- EROSION PENETRATION OF PRIMARY SEAL REQUIRES RELIABLE SECONDARY SEAL FOR PRESSURE INTEGRITY
  - IGNITION TRANSIENT - 10-600 PSI
    - 10-170 MEDIUM PROBABILITY OF RELIABLE SECONDARY SEAL
    - 170-350 MEDIUM PROBABILITY OF RELIABLE SECONDARY SEAL
    - 350-600 MEDIUM PROBABILITY OF NO SECONDARY SEAL CAPABILITY

- STEADY STATE - 1500 PSI - 2 MINUTES
  - IF EROSION PENETRATES PRIMARY O-RING SEAL - HIGH PROBABILITY OF NO SECONDARY SEAL CAPABILITY
    - BENCH TESTING SHOWED O-RING NOT CAPABLE OF MAINTAINING CONTACT WITH METAL PARTS GAP OPENING RATE TO MDSP
    - BENCH TESTING SHOWED CAPABILITY TO MAINTAIN O-RING CONTACT DURING INITIAL PHASE 10-170 PSI OF TRANSIENT

PRIMARY CONCERNS - CONT



UNPRESSURIZED JOINT - NO ROTATION

PRESSURIZED JOINT - ROTATION EFFECT TERMINATION

Blow By History

SRM-15 Worst Blow-By
- 2 Case Joints (80°), (110°) Arc
- Much Worse Visually Than SRM-22

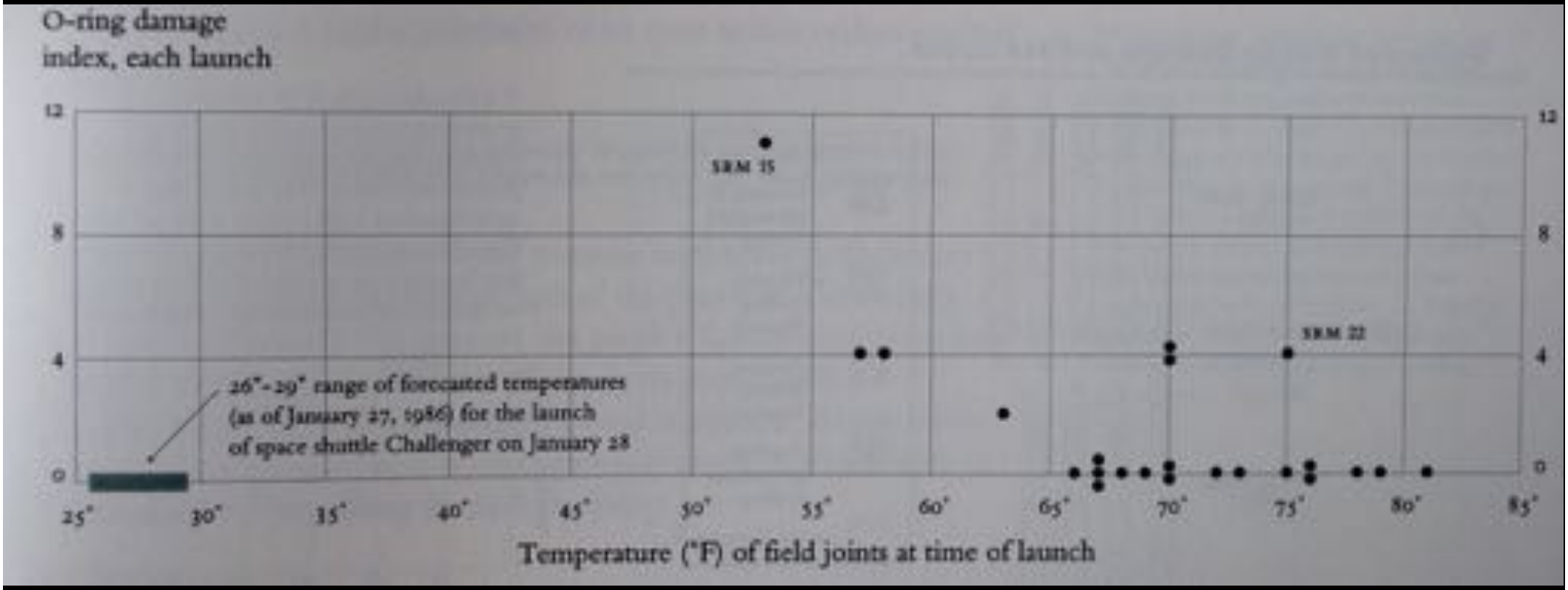
SRM 22 Blow-By
- 2 Case Joints (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A
- Nozzle Blow-By

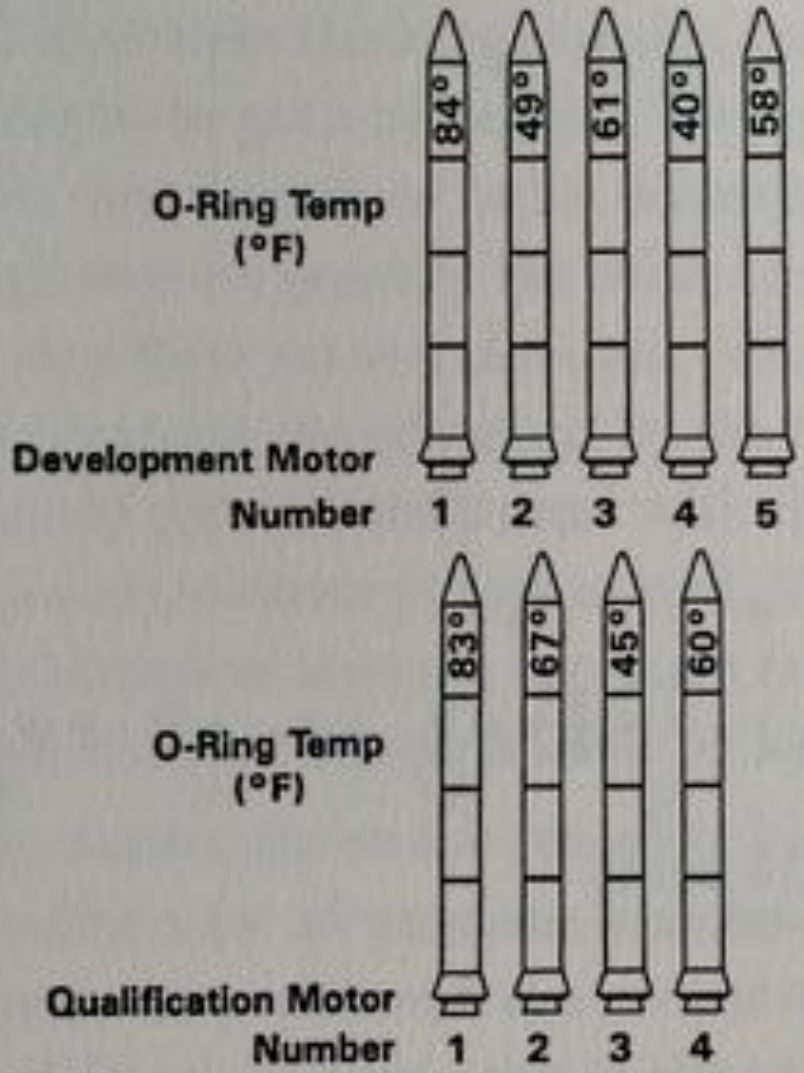
History of O-Ring Temperatures (Degrees-F)

Motor	MBT	Amb	O-Ring	Wind
DM-4	68	36	47	10 mph
DM-2	76	45	52	10 mph
QM-3	72.5	40	48	10 mph
QM-4	76	48	51	10 mph
SRM-15	52	64	53	10 mph
SRM-22	77	78	75	10 mph
SRM-25	55	26	29 27	10 mph 25 mph

Flight	Date	Temperature °F	Erosion incidents	Blow-by incidents	Damage index	Comments
51-C	01.24.85	53°	3	2	11	Most erosion any flight; blow-by; back-up rings heated.
41-B	02.03.84	57°	1		4	Deep, extensive erosion.
61-C	01.12.86	58°	1		4	O-ring erosion on launch two weeks before Challenger.
41-C	04.06.84	63°	1		2	O-rings showed signs of heating, but no damage.
1	04.12.81	66°			0	Coolest (66°) launch without O-ring problems.
6	04.04.83	67°			0	
51-A	11.08.84	67°			0	
51-D	04.12.85	67°			0	
5	11.11.82	68°			0	
3	03.22.82	69°			0	
2	11.12.81	70°	1		4	Extent of erosion not fully known.
9	11.28.83	70°			0	
41-D	08.30.84	70°	1		4	
51-G	06.17.85	70°			0	
7	06.18.83	72°			0	
8	08.30.83	73°			0	
51-B	04.29.85	75°			0	
61-A	10.30.85	75°		2	4	No erosion. Soot found behind two primary O-rings.
51-I	08.27.85	76°			0	
61-B	11.26.85	76°			0	
41-G	10.05.84	78°			0	
51-J	10.03.85	79°			0	
4	06.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea.
51-F	07.29.85	81°			0	


O-ring damage
index, each launch
12
8
4
0
SRM 15
SRM 22
26°–29° range of forecasted temperatures
(as of January 27, 1986) for the launch
of space shuttle Challenger on January 28
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
Temperature (°F) of field joints at time of launch

History of O-Ring Damage in Field Joints



Code

- S = Heating of Secondary O-Ring
- B = Primary O-Ring Blowby
- E = Primary O-Ring Erosion
- H = Heating of Primary O-Ring
- = No Damage

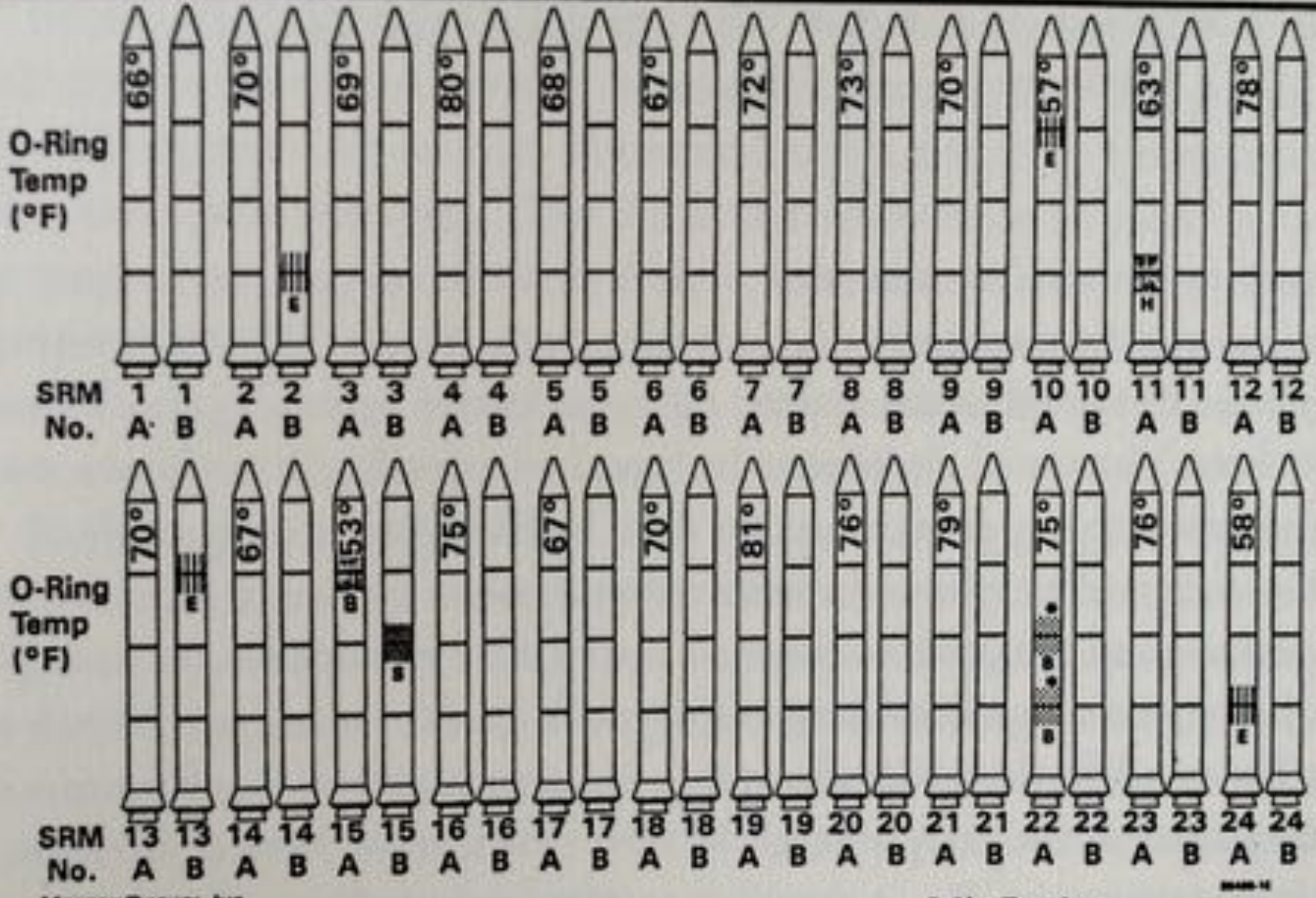
STATIC TEST MOTORS

- HORIZONTAL ASSEMBLY
- SOME PUTTY REPAIRED

MORTON THIOKOL, INC.
Wasatch Operations

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

History of O-Ring Damage in Field Joints (Cont)

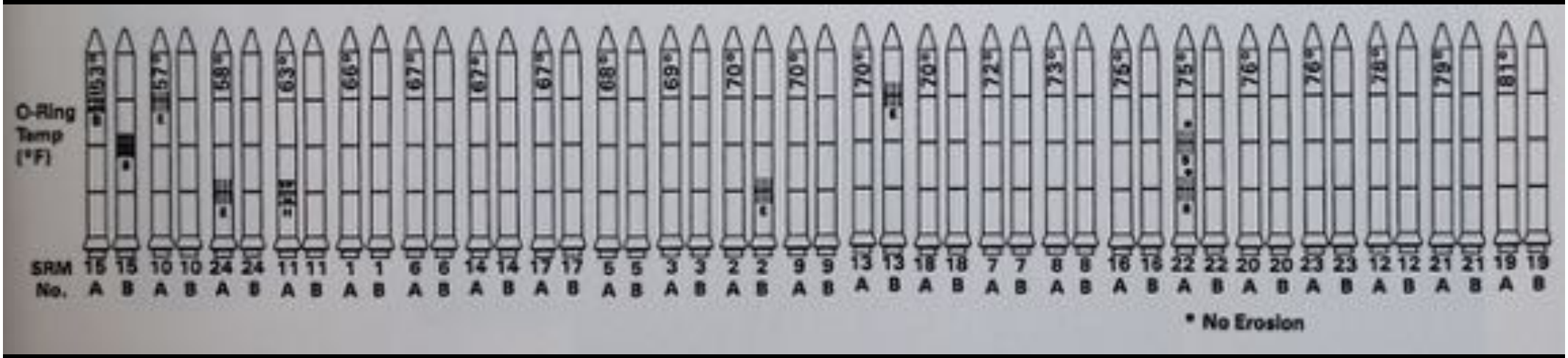


MORTON THIOKOL, INC.
Wasatch Operations

• No Erosion

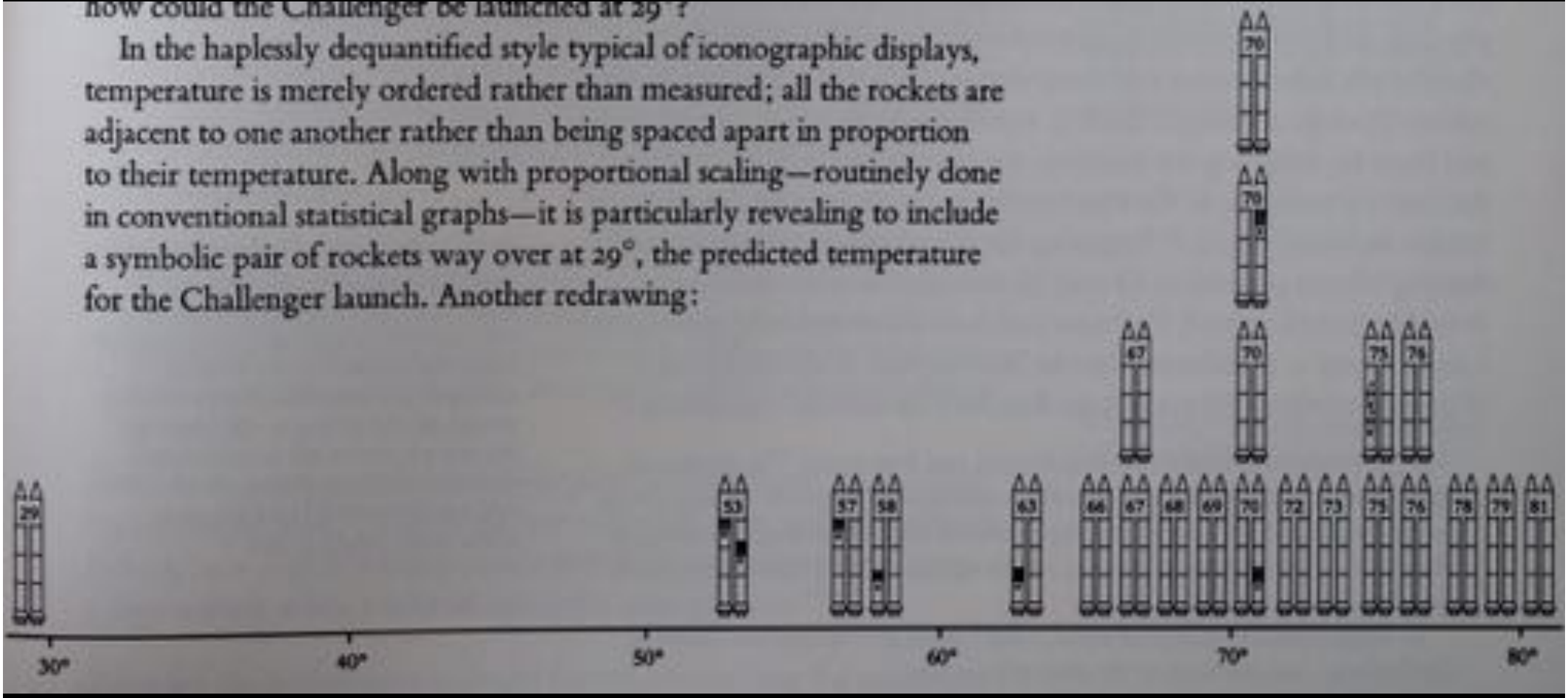
INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION
AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

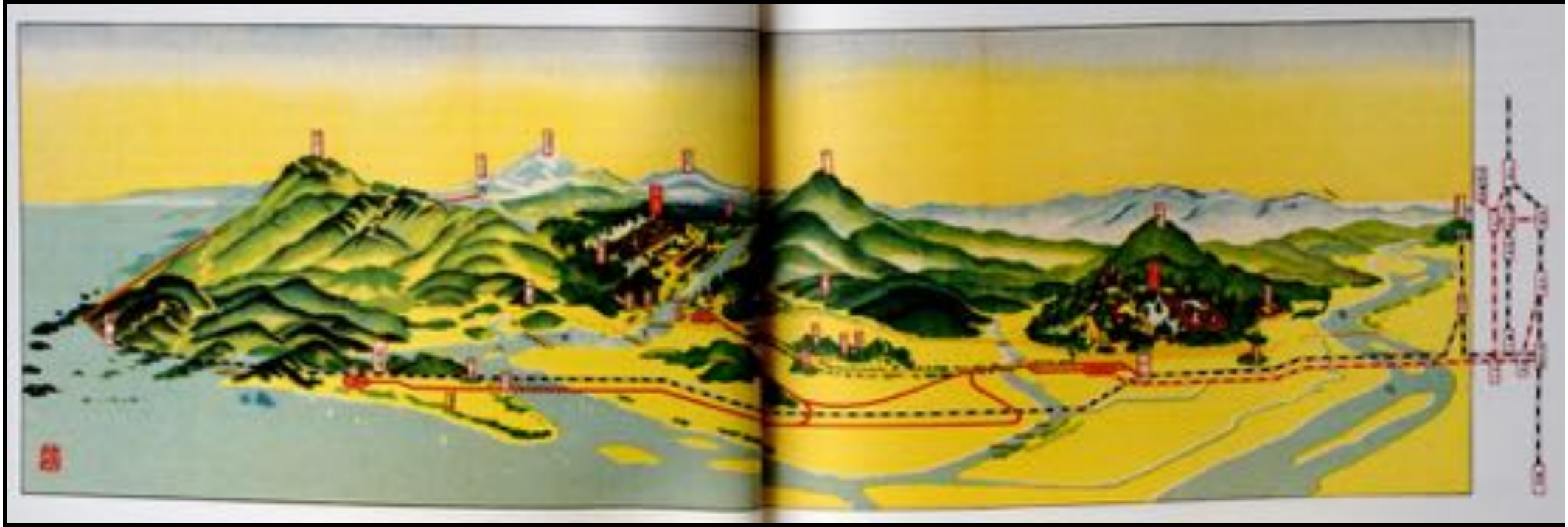

O-Ring Temp (°F)
53°
57°
58°
63°
66°
67°
67°
67°
68°
69°
70°
70°
70°
70°
72°
73°
75°
75°
76°
76°
76°
78°
79°
81°
SRM No.
15 A
15 B
10 A
10 B
24 A
24 B
11 A
11 B
1 A
1 B
6 A
6 B
14 A
14 B
17 A
17 B
5 A
5 B
3 A
3 B
2 A
2 B
9 A
9 B
13 A
13 B
18 A
18 B
7 A
7 B
8 A
8 B
16 A
16 B
22 A
22 B
20 A
20 B
23 A
23 B
12 A
12 B
21 A
21 B
19 A
19 B
* No Erosion

how could the Challenger be launched at 29°?

In the haplessly dequantified style typical of iconographic displays, temperature is merely ordered rather than measured; all the rockets are adjacent to one another rather than being spaced apart in proportion to their temperature. Along with proportional scaling—routinely done in conventional statistical graphs—it is particularly revealing to include a symbolic pair of rockets way over at 29°, the predicted temperature for the Challenger launch. Another redrawing:



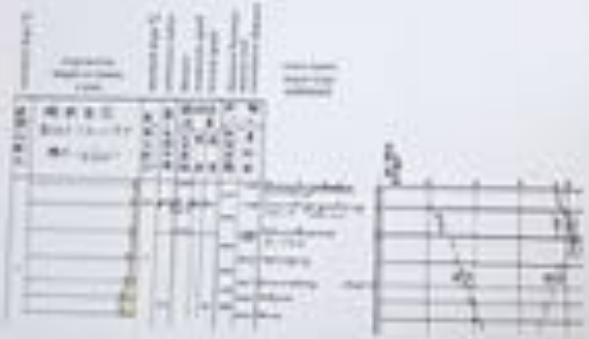
Escape flatland.

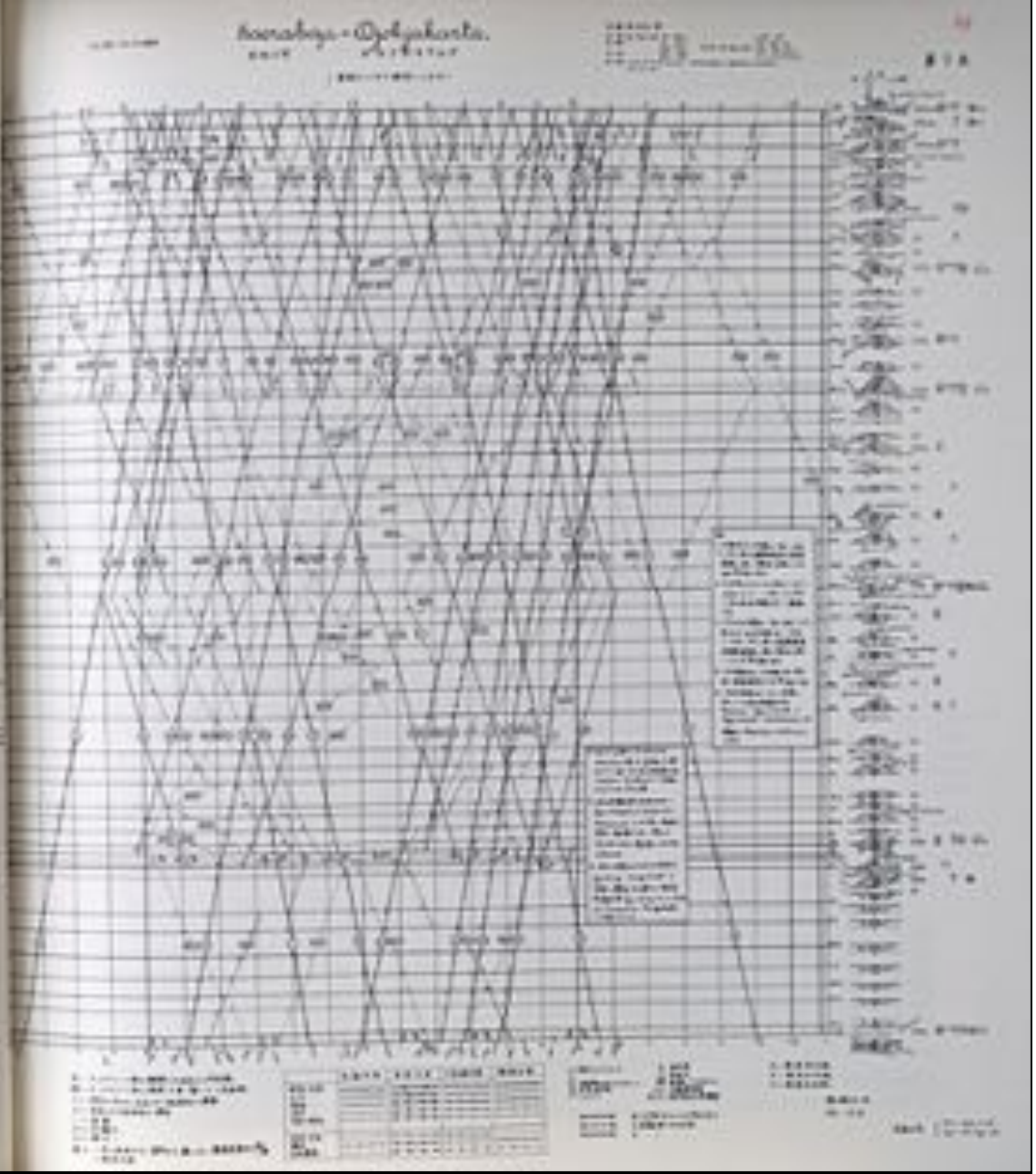


WOODHOUSE compiles a diagraphic timetable for a Java railroad line, Soerabaja-Djokjakarta, drawn in November 1927 (annotated in Dutch, then in Japanese). By smoothly suppressing a dimension first here and then several times there, forming perspective treatments entirely, and changing the focus, this 24-hour railroad plan abstractly traces out multiple paths through three-space and time, in a four-dimensional tour with a dozen other variables carried along.

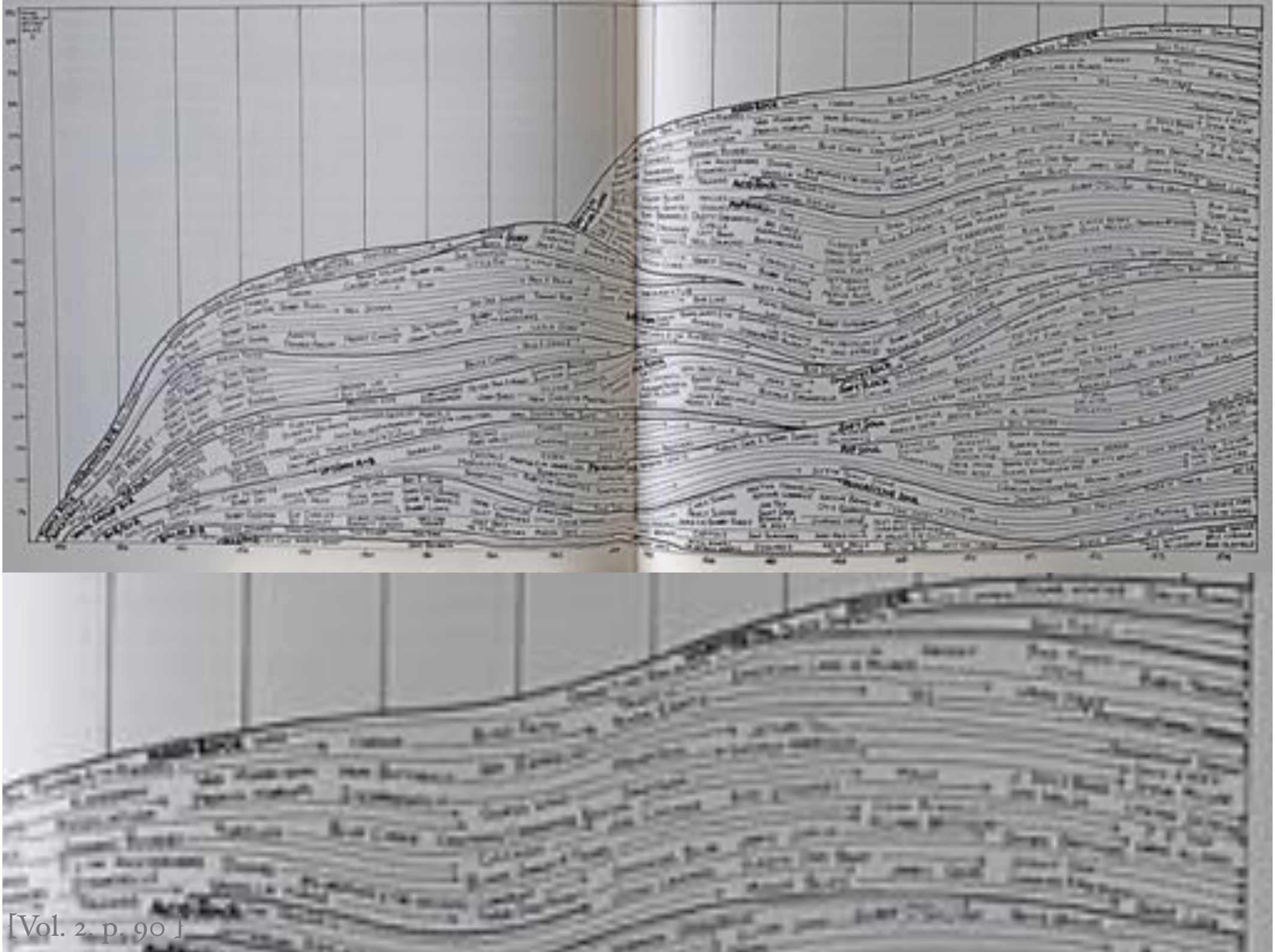
The time scale is read across the top; towns on the railroad route are indicated by names stacked down the column at left. Diagonal lines running from upper left to lower right show trains heading down ↘, return trains by diagonals going from lower left to upper right ↗. The first train from the top station, Soerabajakota, leaves at about 4:30 in the morning (at the ← dot), and then reaches the first stop just a few minutes later, and so on. Steeper lines are the faster trains. When trains going opposite directions pass by, an X appears. The arrangement repays meticulous study:

- *Graphical timetables* turn the *three spatial dimensions* of our daily world into one train-relevant dimension by measuring distance along the track itself. Horizontal grid lines, marking towns and station stops, are spaced approximately in proportion to their *distance* apart along the rails (yielding straight-line diagonals, assuming trains run more or less at *constant speed* over the entire route).
- The left margin of the timetable reflects another viewpoint, with a *profile* (at an enlarged vertical scale) of all the valleys and mountains crossed by rail. This visual depiction is accompanied by quantitative details, to the right of the profile, where columns of numbers describe the grade and path. Note how the vertical has been used repeatedly to





array parallel sequences of thoroughgoing data. In Roland, after all, every opportunity to spread additional information over an already-available dimension must be cherished.



[Vol. 2, p. 90]

Use layering & separation.

(1 + 1 = 3 or more)

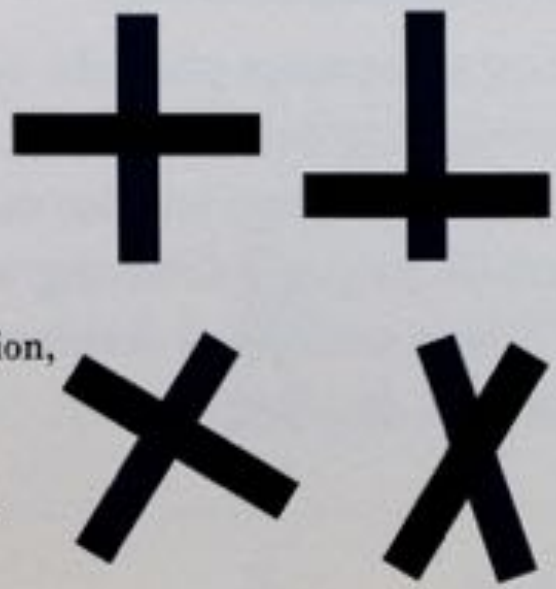
Here I have 2 equal strips of cardboard (1" x 6")

Here is one (vertical), here another (also vertical).
Seeing one strip plus one strip, we count 2 strips:
$1 + 1 = 2$.

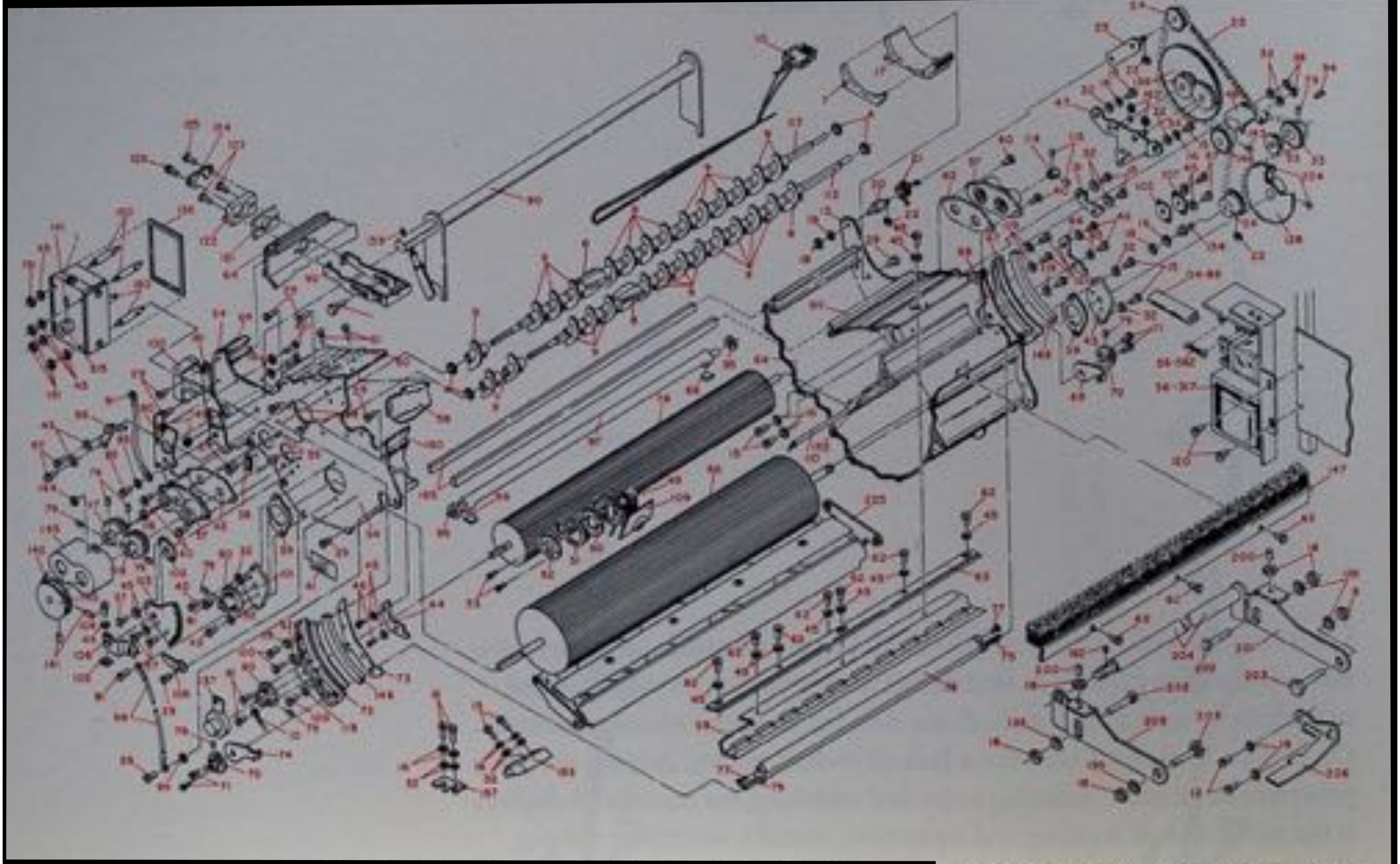
We recognize the equal width of the strips.
Now, 1 width + 1 width (strips touching)
equals 2 widths: $1 + 1 = 2$.

But now, separating them (both remain vertical)
by 1 width — we count 3 widths
(one of them negative): $1 + 1 = 3$.

Of the 2 vertical strips,
one crosses the other horizontally
in their centers.
Result: 2 lines form a crossing
thus producing 4 arms, as 4 extensions,
to be read inward as well as outward.
We also see 4 rectangles, and with some imagination,
4 triangles, 4 squares.
By shifting centers and angles,
arms and the in-between figures become unequal.

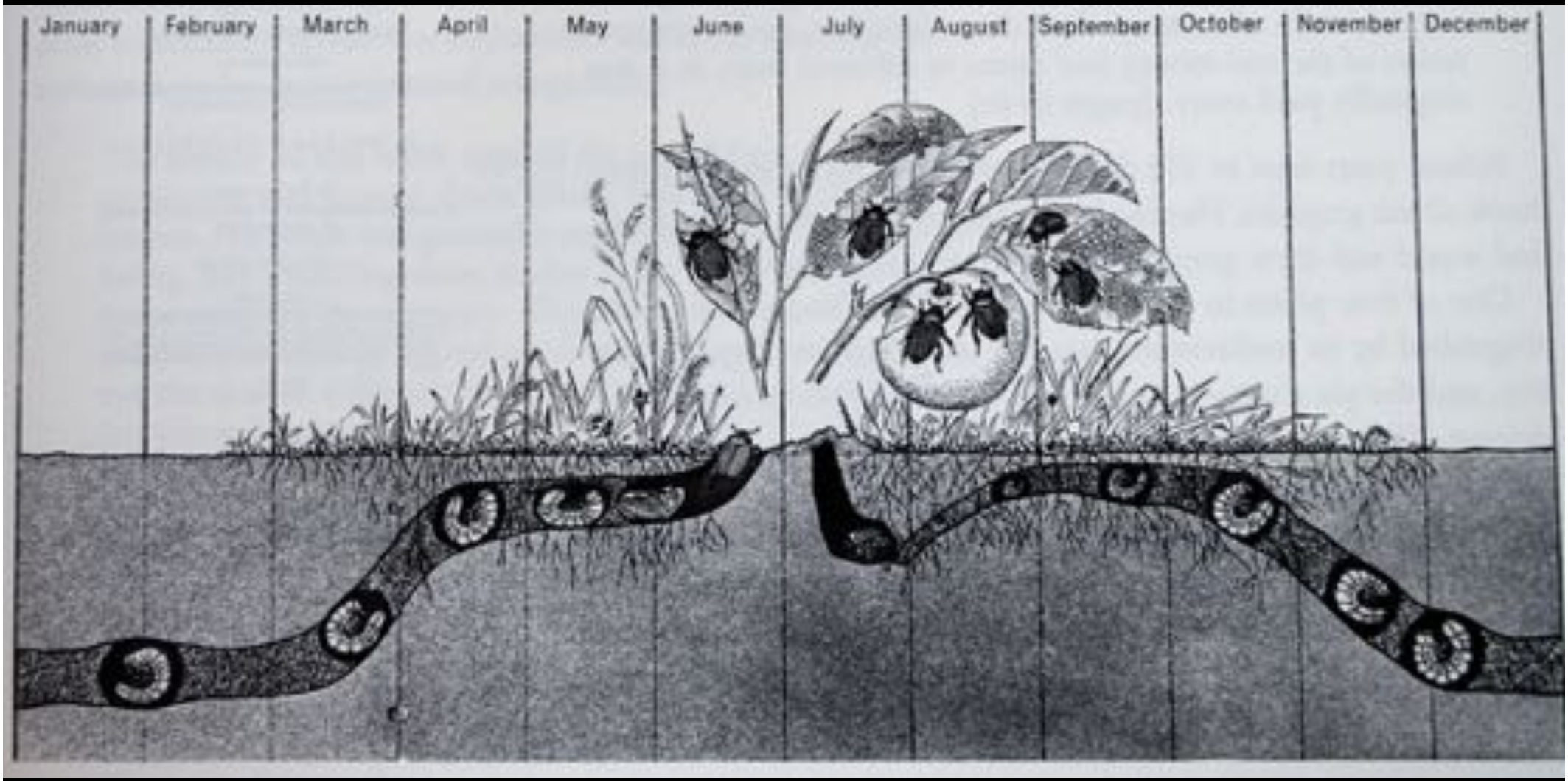


All together: one line plus one line
results in many meanings — *Quod erat demonstrandum.*

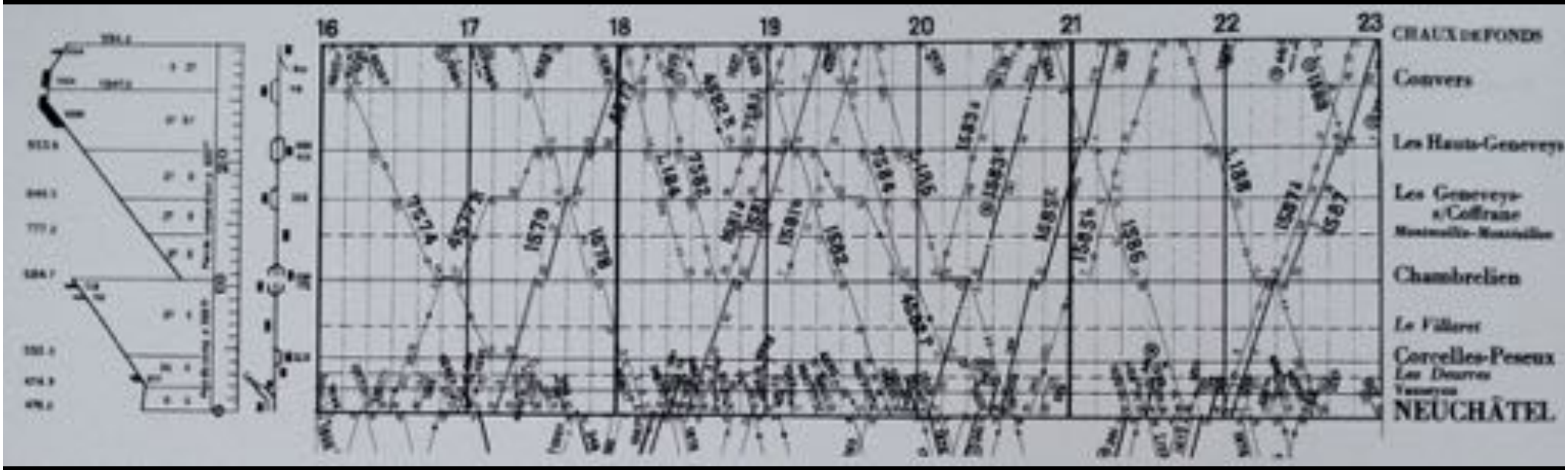


IBM Series III Copier/Duplicator, Adjustment Parts Manual (Boulder, Colorado, 1976), p. 101. Drawn by Gary E. Graham.

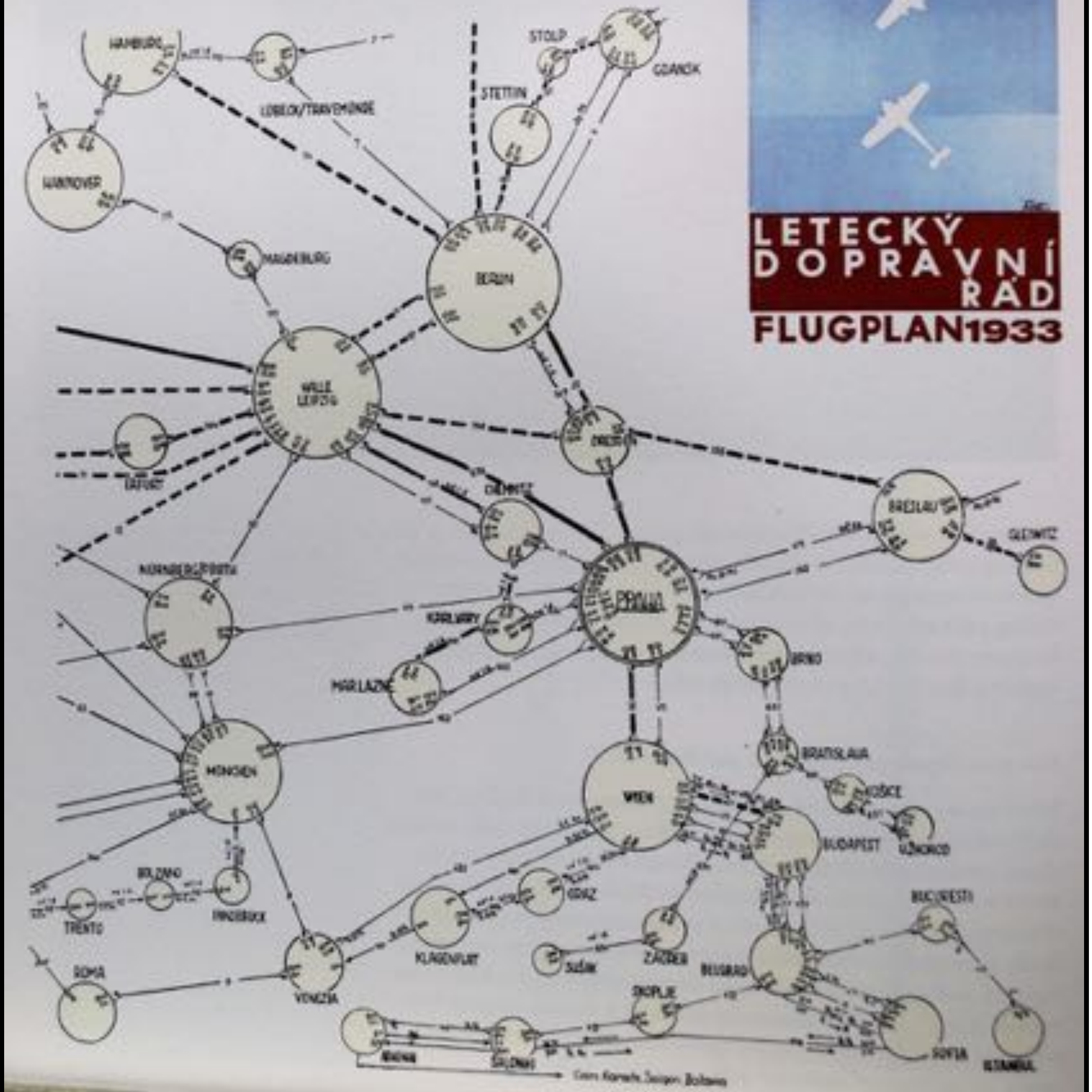
Utilize narratives of space & time.



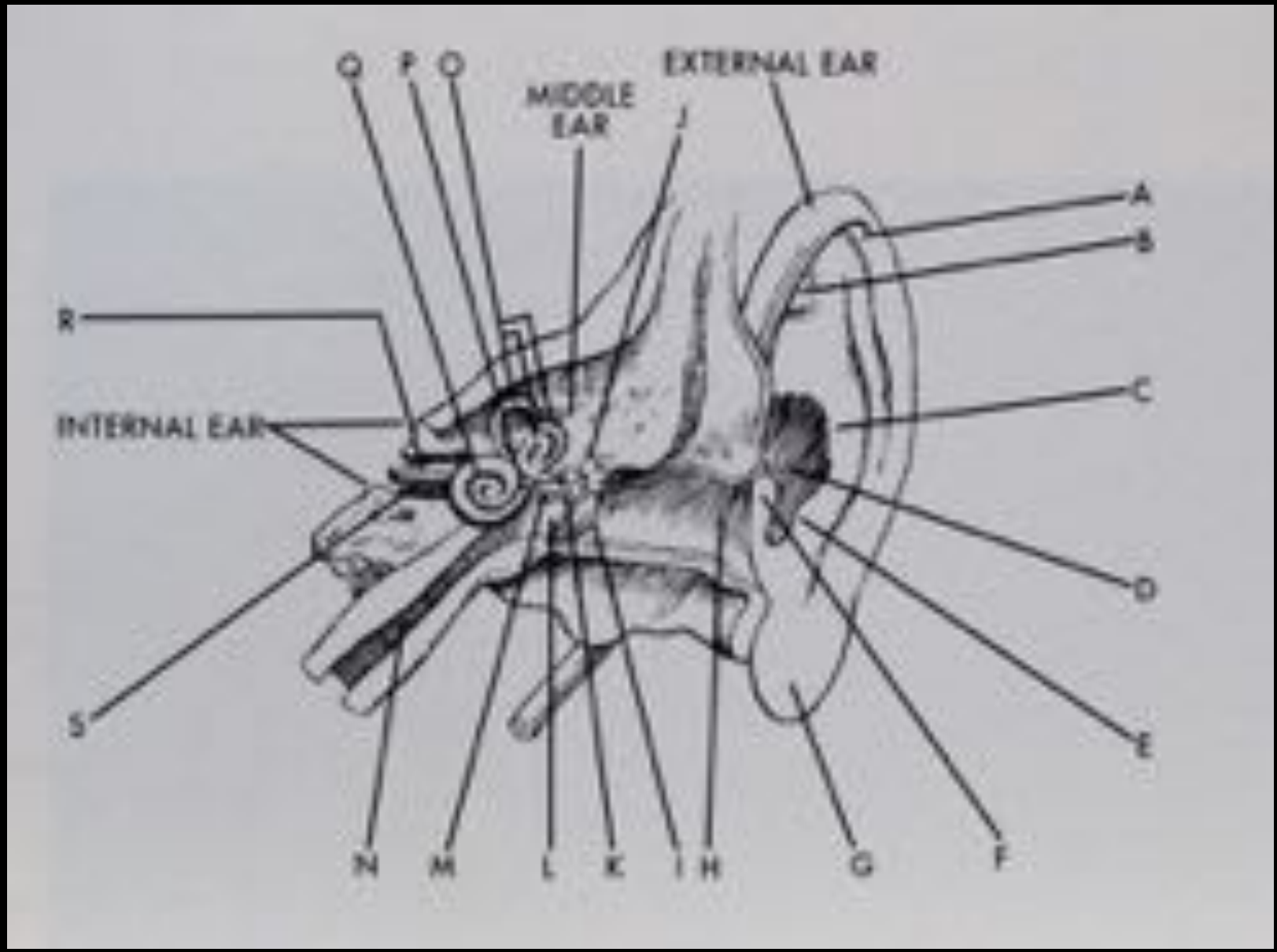
[Vol. 1, p. 43; Vol. 2, p. 110]

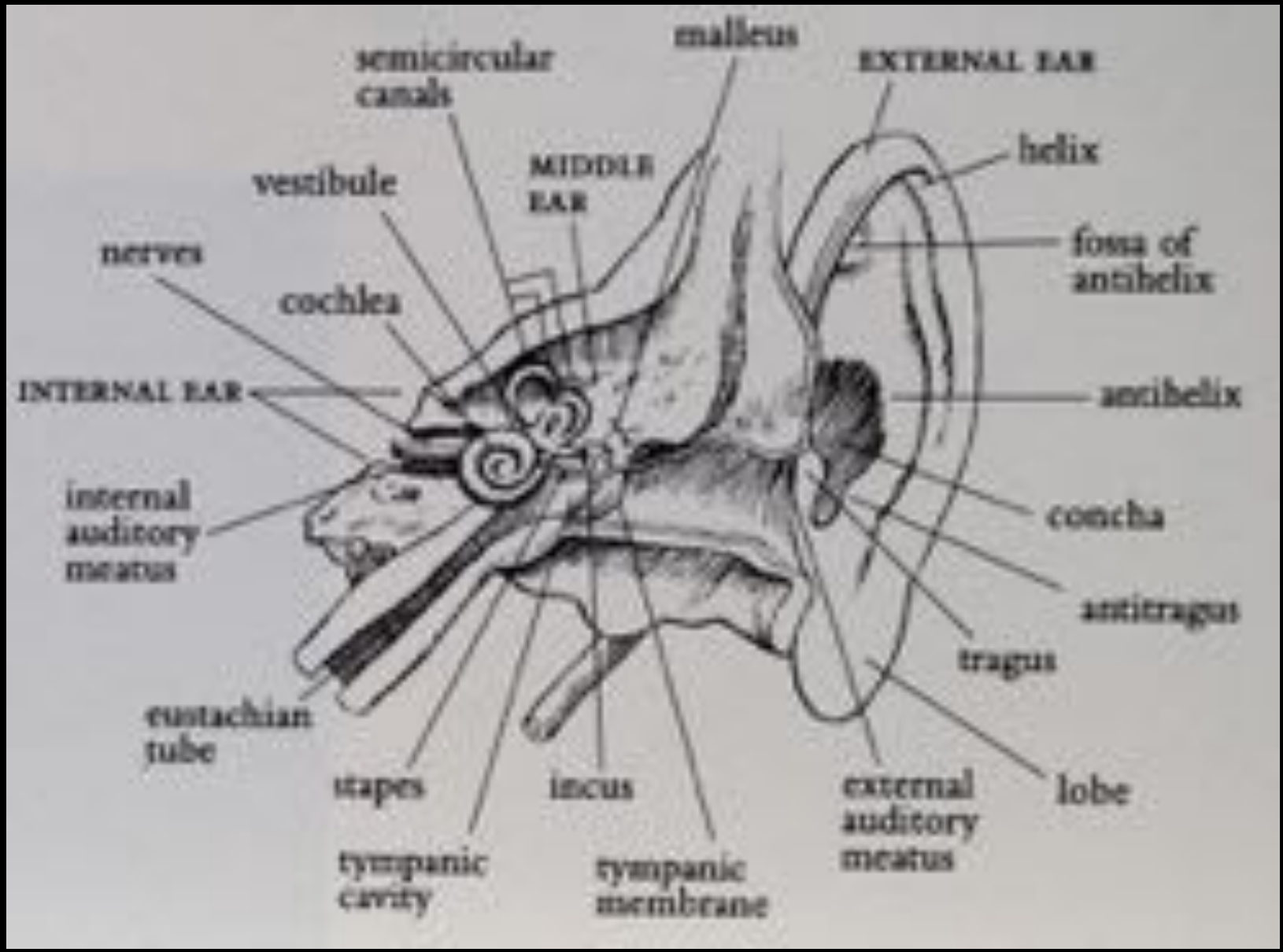

16
17
18
19
20
21
22
23
CHAUX-DE-FONDS
Convers
Les Hauts-Geneveys
Les Geneveys-s/Coffrane
Chambrelien
Le Villaret
Corcelles-Peseux
NEUCHÂTEL

[Vol. 2, p. 102]


LETECKÝ
DOPRAVNÍ
ŘÁD
FLUGPLAN1933
HAMBURG
LÜBECK/TRAVEMÜNDE
STOLP
GDANSK
STETTIN
HANNOVER
MAGDEBURG
BERLIN
HALLE LEIPZIG
ERFURT
DRESDEN
CHEMNITZ
BRESLAU
GLEIWITZ
NÜRNBERG/FÜRTH
KARLVARY
MAR.LAZNĚ
PRAHA
BRNO
BRATISLAVA
KOŠICE
UŽHOROD
MÜNCHEN
WIEN
BUDAPEST
BOLZANO
TRENTO
INNSBRUCK
GRAZ
KLAGENFURT
SUŠAK
ZAGREB
BEOGRAD
BUCUREŞTI
ROMA
VENEZIA
SKOPLJE
SOFIA
ISTANBUL
SALONIKI

Content is king.


EXTERNAL EAR
MIDDLE EAR
INTERNAL EAR
A
B
C
D
E
F
G
H
I
K
L
M
N
O
P
R
S


malleus
semicircular canals
EXTERNAL EAR
helix
vestibule
MIDDLE EAR
fossa of antihelix
nerves
cochlea
INTERNAL EAR
antihelix
internal auditory meatus
concha
antitragus
tragus
eustachian tube
stapes
incus
external auditory meatus
lobe
tympanic cavity
tympanic membrane

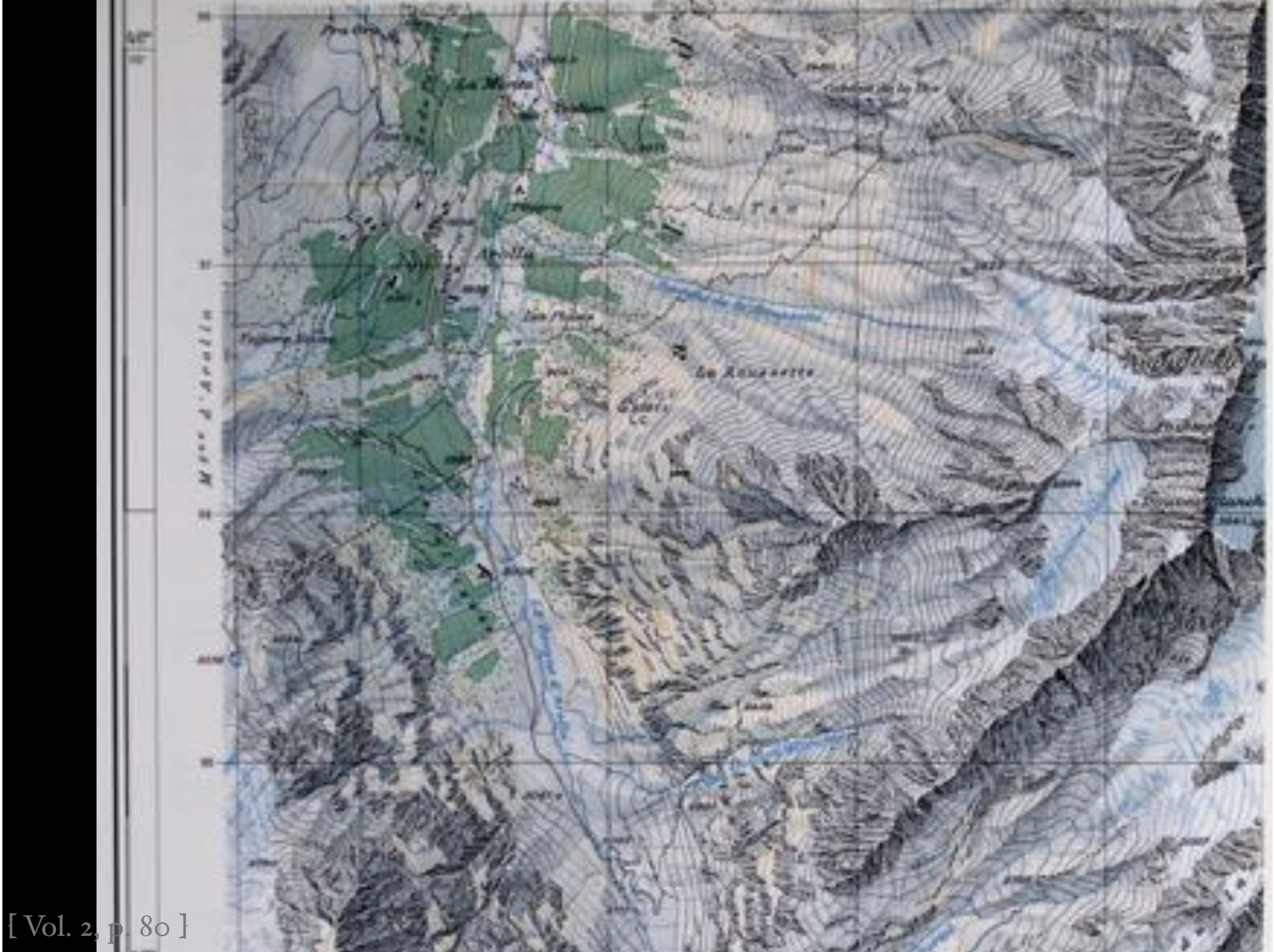

Marshalling Signals
PROCEED: MATCH SIGNALS
THIS WAY
PROCEED to NEXT SIGNALMAN
TURN LEFT
TURN RIGHT
MOVE AHEAD
STOP
START ENGINES
INSERT CHOCKS
PULL CHOCKS
CUT ENGINES
SLOW DOWN
SLOW DOWN LEFT ENGINES


MARSHALLING SIGNALS
PROCEED: WATCH SIGNALS
THIS WAY
PROCEED TO NEXT SIGNALMAN
TURN LEFT
TURN RIGHT
MOVE AHEAD
STOP
START ENGINES
INSERT CHOCKS
PULL CHOCKS
CUT ENGINES
SLOW DOWN
SLOW DOWN LEFT ENGINES

“The often scant benefits derived from coloring data indicate that even putting a good color in a good place is a complex matter. Indeed, so difficult and subtle that avoiding catastrophe becomes the first principle in bringing color to information: **Above all, do no harm.**”

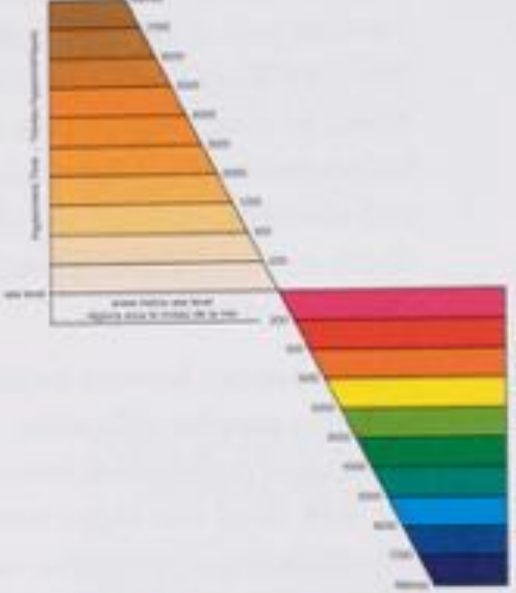
Use color to:

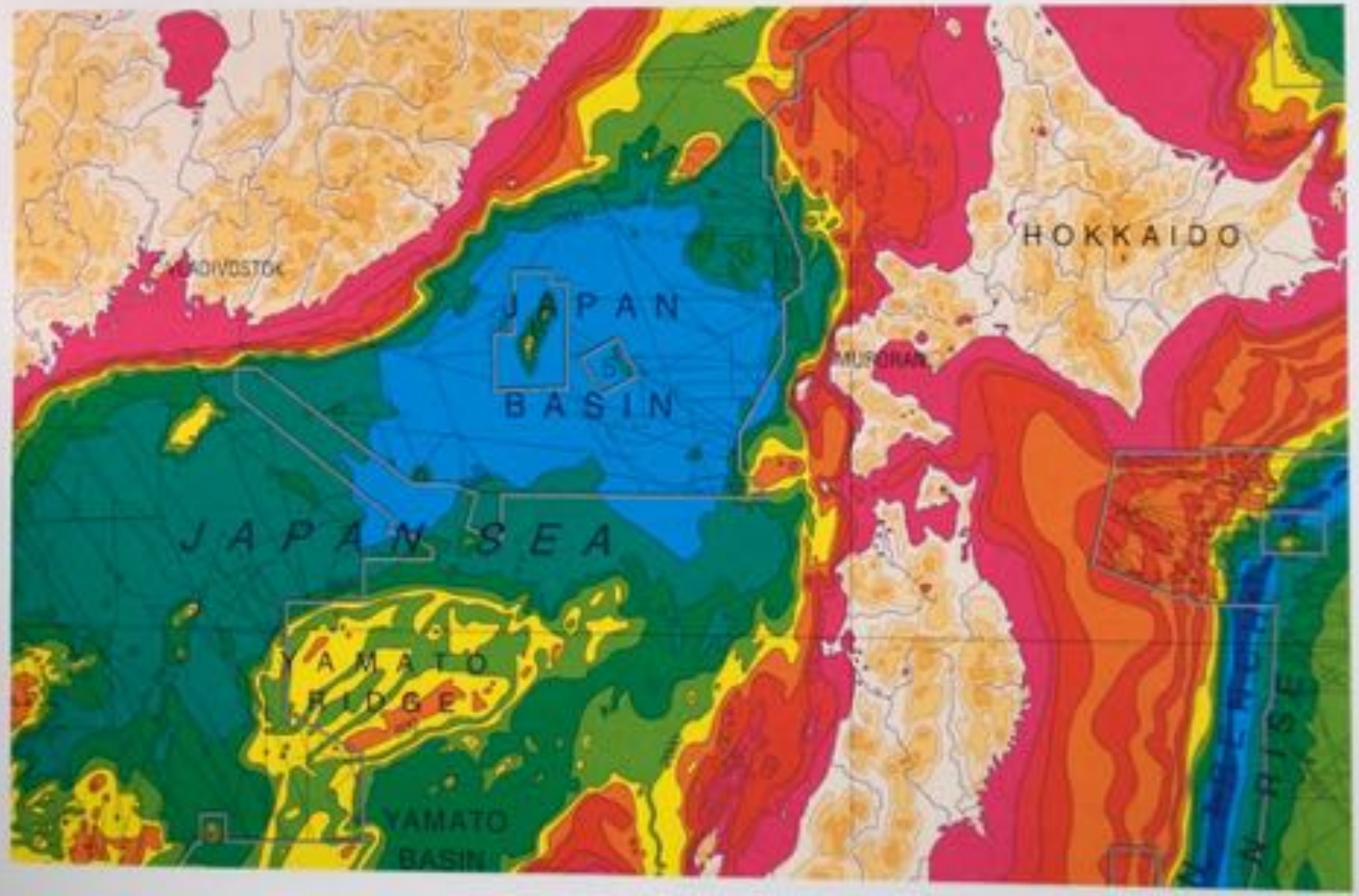
- label
- measure
- represent or imitate reality
- enliven or decorate


Mont d'Arolla
La Tsa
La Rousette

often found in scientific publications, such a visually naive color-scale would be laughed right out of the field (or ocean) of cartography. These aggressive colors, so unnatural and unquantitative, render the map incoherent, with some of the original data now lost in the soup.

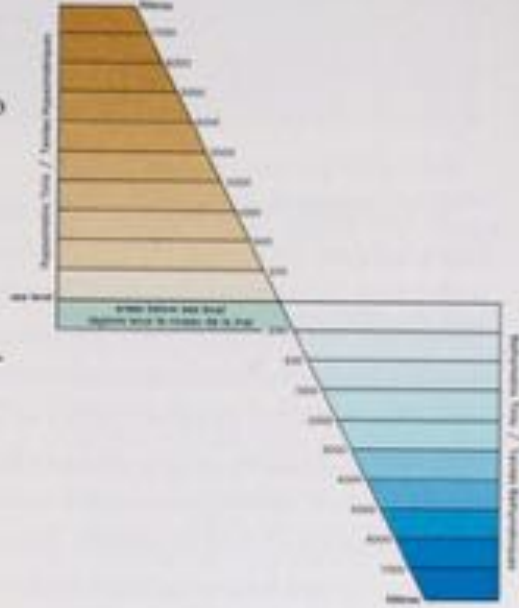
Minimal distinctions reduce visual clutter. Small contrasts work to enrich the overall visual signal by increasing the number of distinctions that can be made within a single image; thus design by means of small effective differences helps to increase the resolution of our images. In practice, the appropriate size of small contrasts will depend on the context, priority of particular elements in the overall visual story, number of differentiations made within an image, and characteristics of those viewing the image. Despite these local complications, the global principle of the smallest effective difference resolves many visual issues—serving perhaps even as an algorithm for automated design.

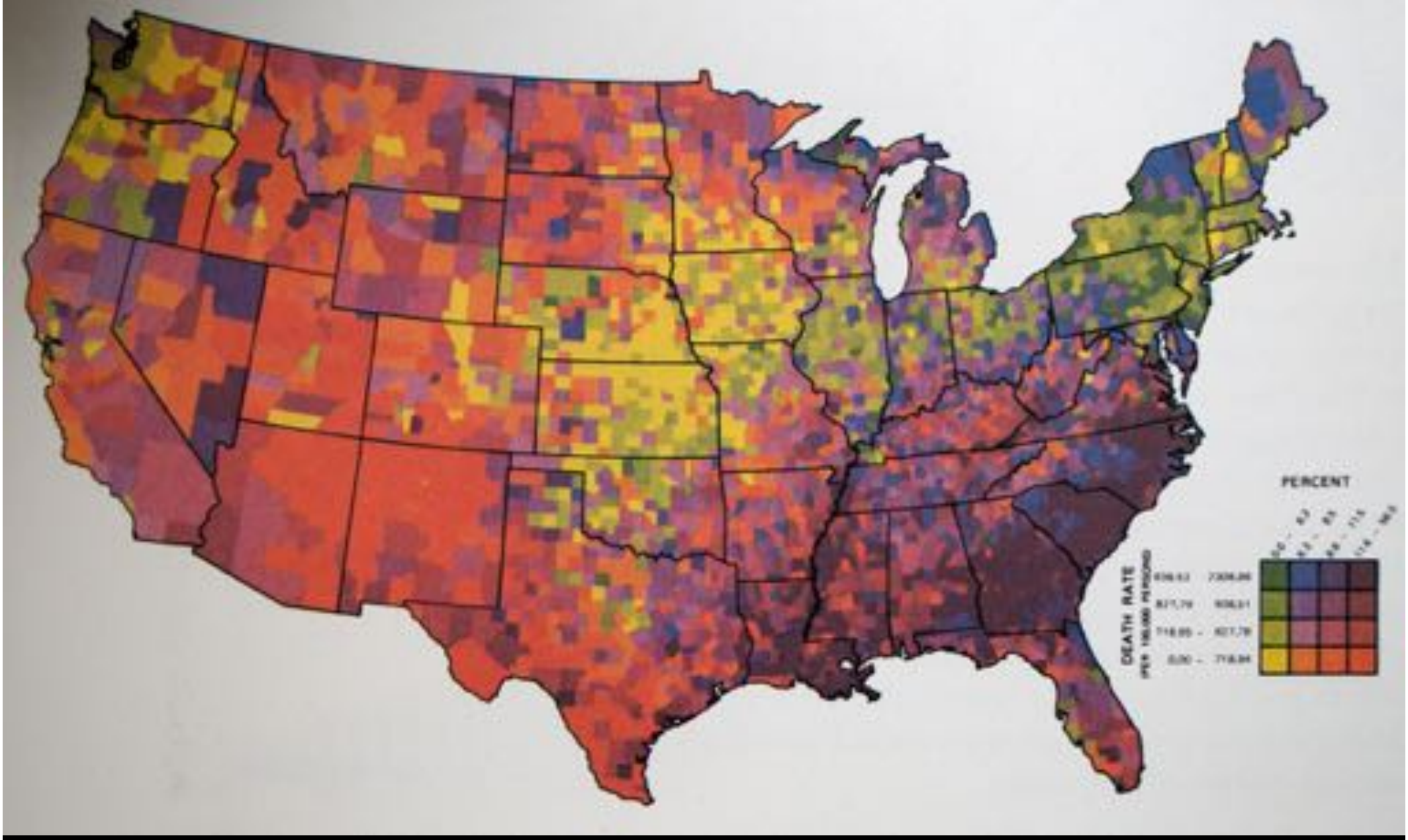




shading to the glowing symphony of color. What perspectives in the dimension of meaning!" wrote Paul Klee.[8] In practice everything is not this wonderful, given the frequently uneasy translations from number to corresponding color and thence to human readings and interpretations.

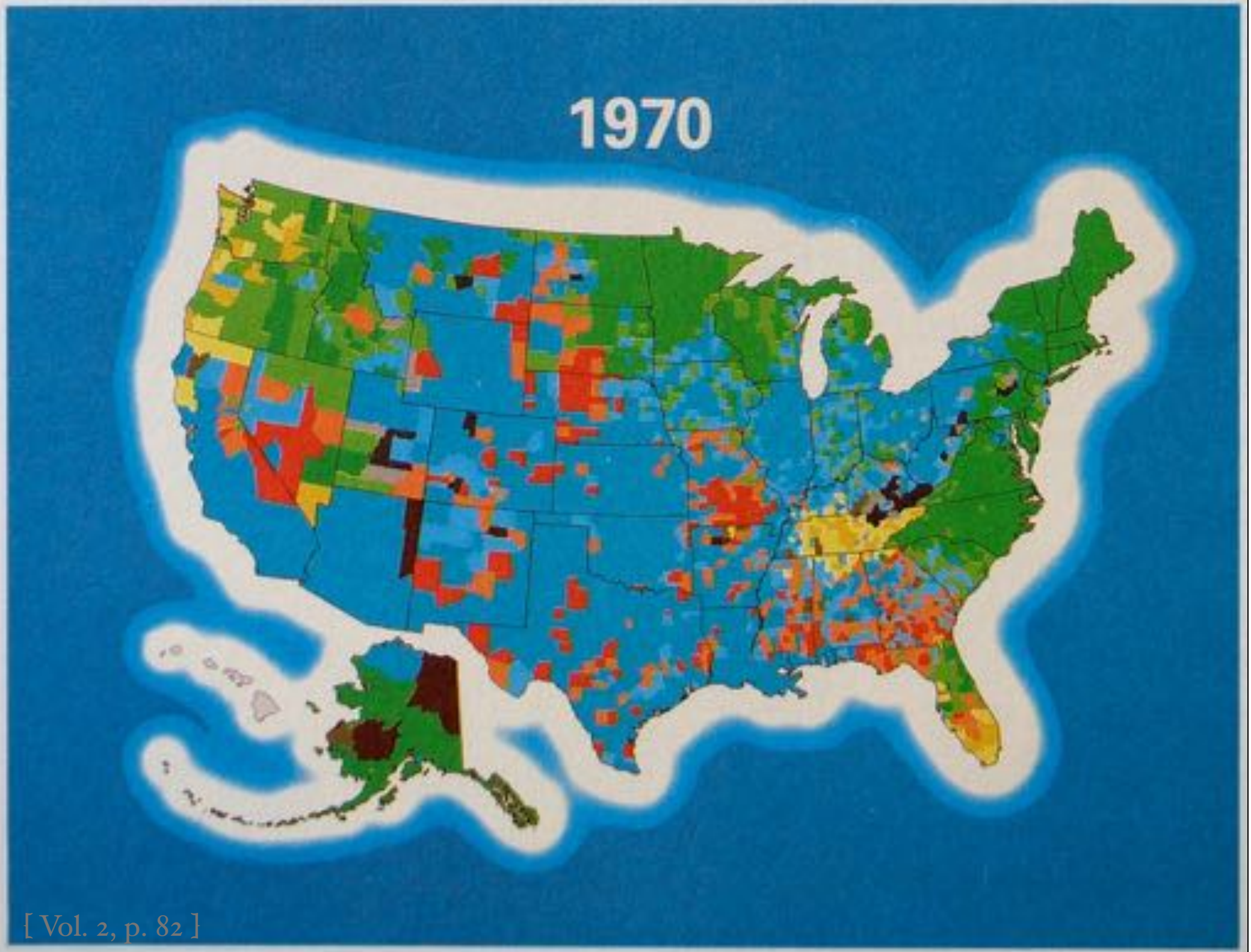
The General Bathymetric Chart of the Oceans records ocean depth (bathymetric tints) and land height (hypsometric tints) in 21 steps—with "the deeper or higher, the darker" serving as the visual metaphor for coloring. Shown are the great ocean trenches of the western Pacific and Japan Sea. Numbered contours outline color fields, improving accuracy of reading. Nearly transparent gray tracks, on a visual plane apart from the bathymetric tints, trace paths of sounding lines (outside those areas of extremely detailed surveys, such as ports and along coast lines). Every color mark on this map signals four variables: latitude, longitude, sea or land, and depth or altitude measured in meters.

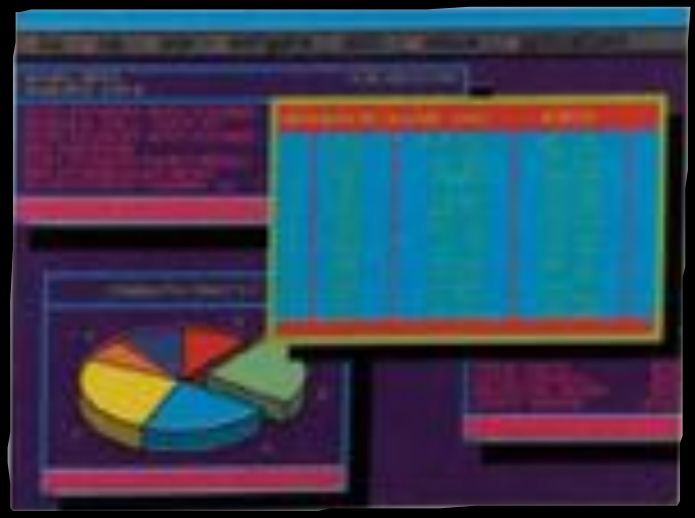




"Seeing is forgetting the name of the thing one sees." — Paul Valéry

[Vol. 1, p. 153]


1970



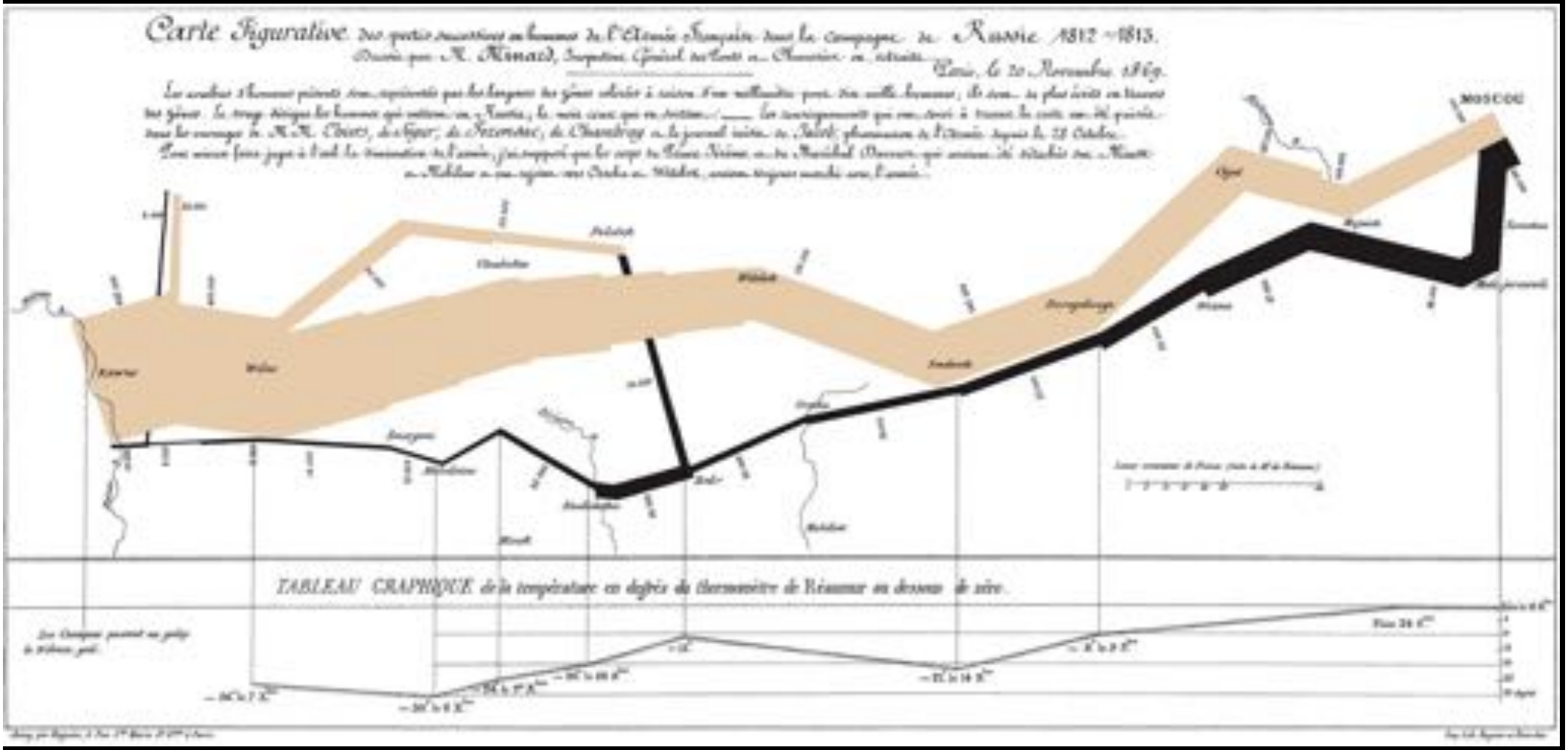
Attractive displays of statistical info

* have a properly chosen format and design
* use words, numbers and drawing together
* reflect a balance, a proportion, a sense of relevant scale
* display an accessible complexity of detail
* often have a narrative quality, a story to tell about the data
* are drawn in a professional manner, with the technical details of production done with care
* avoid content-free decoration, including chartjunk

Information Overload

“Clutter and confusion are failures of design, not attributes of information.”

[Vol. 2, p. 51]


Carte Figurative
MOSCOU
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Graphical Displays Should

* Show the data
* Induce the viewer to think about substance rather than about methodology, graphic design the technology of graphic production, or something else
* Avoid distorting what the data have to say
* Present many numbers in a small space
* Make large data sets coherent
* Encourage the eye to compare different pieces of data

Graphical Displays Should

* Reveal the data at several levels of detail, from a broad overview to the fine structure
* Serve a reasonably clear purpose: description, exploration, tabulation, or decoration
* Be closely integrated with statistical and verbal descriptions of a data set