APPENDIX.

No. 1.

Observations on Subterranean Temperature in the Mines of Cornwall and Devon.

My Geological Survey of the Mines in the Duchy of Cornwall afforded many opportunities for observations on subterranean temperature, of which I always availed myself.

After most careful consideration of the subject, and consultation with others who have also been engaged in this enquiry, it has been thought best to confine the observations, as much as possible, to the temperature of the streams of water immediately issuing from the unbroken portions of the rocks and veins.

The reasons for this preference are:—that the temperature of the *air* in mines is affected, not only by the presence of the workmen, the combustion of candles, and the explosion of gunpowder, but also by the warm or cold air which is brought to the same spot by the varying directions of the currents underground, which are more or less influenced by the changes of wind at the surface:—that the *rocks*, forming the sides of the shafts and levels, must, to a certain extent, partake of the temperature of the air circulating through them; and, of course, be affected by its changes:—and, that the water flowing through, or standing in pools, in the levels, is exposed to the same modifying causes, and probably, also, warmed by the workmen who frequently stand in it.

As all these causes operate irregularly, it is difficult, if not altogether impossible, to select any distant periods at which their influence should be the same. The present observations were therefore made on the water as it issued from the unbroken rock, before the streams could be affected by the temperature of the levels: and they were, for the most part, instituted where frequent excavations scarcely permit even the apertures to partake of that influence, whilst the more deeply seated portions of their channels are perfectly free from it.

In a few instances, however, the temperatures, both of the air and rocks, were observed, and these are expressly mentioned.

The particulars of each observation will be found in the first of the following tables; and the results deduced from them, in the others.

TABLE No. 1.

THE SAINT JUST DISTRICT.[1]

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Cunning (Granite).		
Small,[2] out of *lode*, end[3]	70·	56°·0
" " bottom	90·	59°·0
Drawn to adit by engine from	80·	51°·0*
Little Bounds (Granite).		
Small, out of *lode*, end	10·	49°·5
" pool collected in the adit	"	52°·0
Wheal Edward (Granite).		
Small, pool collected from droppings	65·	53°·0
" " "	75·	59°·0
Park-noweth (Granite).		
Small, out of *lode*	21·	50°·0
" "	44·	51°·0
" "	54·	51°·0
" "	61·	57°·0
Drawn to adit by the engine	"	52°·75*
Botallack (Slate).		
Small, out of *lode*	44.	51°·0
" " end, W.	69·	54°·0
" out of rock, N. of *lode*	99·	61°·0
Drawn to adit by engine (*Narrow*) from	"	56°·0*
" " (*Crowns*) "	145·	59°·0
Wheal Cock (Slate).		
Small, out of *lode*, very salt	120·	59°·0
Drawn to adit by engine from	"	52°·0*
Levant (Slate).		
Small, out of *lode*, E.	24·	51°·0
" " E.	138·	66°·0
" " W.	"	67°·0
Drawn to adit by engine from	"	61°·0*
Boscaswell Downs (Granite).		
Collected in adit	26·	49°·0
Small, out of *lode*, end, W.	116·	59°·0
" collected in level	156·	61°·0
Drawn to adit by engine from	"	51°·0*

* The observations thus marked are not included in the averages given in Tables ii., iii., iv., and v.

1 Observations on the temperature of *Botallack*, *Little Bounds*, and *Levant*, by Dr. Forbes, Dr. Davy, Dr. Barham, and Mr. R. W. Fox, are described, Corn. Geo. Trans, ii. pp. 175, 178; ibid, iii. p. 151; Edin. Journal of Science, iii. p. 75; Report of British Assoc., vi. p. 134.

2 The first word in each line denotes the dimensions of the stream; all the others (3) describe the locality.

SAINT JUST DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
South Wheal Rose (Granite).		
Small, out of *lode*, end, E.	13·	52°·0
" " "	"	52°·5
" " "	31·	53°·0
" " "	53·	55°·5
Drawn to adit by engine from	35·	55°·0*
THE SAINT IVES DISTRICT.[1]		
Morvah and Zennor Mines (Granite).		
Large, out of *lode*, end, E.	28·	53°·0
" " " W.	"	52°·0
Small, out of *trawn*	"	53°·0
Large, "	40·	54°·0
" out of *lode*	50·	56°·0
Drawn to adit by engine from	60·	55°·5*
Ding Dong (Granite).		
Collected in bottom of shaft	79·	55°·5
Trevidgia (Granite).		
Collected in level from oozing out of *lode*	52·	54°·0
Drawn to adit by engine from	"	50°·5*
Rosewall Hill (Granite).		
Small, out of *lode*, W.	25·	48°·5
" " "	40·	51°·0
" " "	70·	53°·0
Saint Ives Consols (Granite).		
Small, out of *lode*, W.	18·	57°·0
" " "	77·	60°·5
Three small streams jetting out of N. *wall*	97·	64°·5
Small, out of *lode*, W.	107·	65°·0
" " back, W.	135·	69°·0
" jetting out of rock, S. *wall*	"	71°·0
Wheal Trenwith (Slate).		
Small, out of *lode*, W.	30·	55°·5
Large, " *trawn*	80·	66°·0
" " *lode*, bottom, W.	110·	66°·0
Providence Mines (Granite).		
Drawn to adit by engine from	36·	60°·0*
Wheal Speed (Granite).		
Drawn to adit by engine from	58·	52°·5*
Balnoon (Granite).		
Small, out of rock, end, W.	36·	56°·0

1 The temperature in *Ding Dong* was ascertained by Dr. Forbes, Corn. Geo. Trans. ii. p. 181.

SAINT IVES DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Reeth **(Granite).**		
Small, out of *lode*, W.	27·	53°·0
Water, a hole 6 ins. deep in Rock, N. *wall*	197·	65°·0
„ collected in bottom of shaft	207·	68°·5
Small, from back *lode*, W.	„	70°·0
Water, a hole in rock, N. *wall*, W.	227·	73°·0
„ collected in bottom of shaft	237·	69°·5
Small, out of *lode*, end, E.	„	71°·5
„ „ „ W.	„	75°·0
„ out of rock „ „	247·	76°·0
Drawn to adit by engine from	207·	56°·0*
Wheal Mary **(Granite).**		
Small, out of *lode*, E.	10·	53°·0
„ „ W.	21·	52°·0
„ „ E.	51·	57°·0
Very small, out of rock, S. *wall*	71·	58°·25
Drawn to adit by engine from	91·	56°·75*
Lelant Consols **(Granite).**		
Small, out of rock, N. *wall*	33·	55°·0
„ „ *lode*, E.	80·	60°·5
Reeth Consols **(Granite).**		
Small, out of *lode*, W.	98·	63°·75
Moderate, „ E.	111·	63°·75
West Poldice **(Slate).**		
Small, out of *lode*, back, E.	44·	60°·0
„ „ rock, N. *wall*	„	57°·0
Large, „ *lode*, back, E.	64·	62°·0
Very large indeed, out of rock, N. *wall*	73·	63°·5
Halsetown, a well in granite at the surface	—	47°·0*
THE MARAZION DISTRICT.[1]		
Wheal Elizabeth **(Slate).**		
Small, out of *lode*, end, W.	4·	54°·5
„ „ *flucan*	24·	55°·0
West Godolphin **(Slate).**		
Small, out of *lode*, end, E.	27·	58°·5
Wheal Bolton **(Slate).**		
Small, out of *north lode*, back, E.	23·	57°·0
„ „ *middle lode* „	65·	63°·0
„ „ rock, S. *wall*	„	63°·0
„ „ *south lode*, back	„	61°·0
Large, „ *caunter lode*	77.	64°·0
„ „ *south lode*, E.	„	64°·0
„ „ rock, S. *wall*	„	63°·0

1 The temperature in *Wheal Neptune* was observed by Dr. Forbes, Corn. Geo. Trans., ii. p. 179.

MARAZION DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Rospeath **(Slate).**		
Very large, out of *lode*, E.	52·	64°·0
" " W.	"	58°·0
Drawn to adit by engine from	"	59°·0*
Great Wheal Fortune **(Slate).**		
Large, out of *lode*	134·	73°·0
" " rock, N. *wall*	"	73°·0
" " " S. "	"	70°·0
" " *lode*	144·	73°·0
" " rock, both *walls*	"	73°·0
Gwallon **(Slate).**		
Small, out of *lode*, back, W.	45·	60°·0
Large, " E.	"	62°·5
" " "	55·	64°·0
Drawn to adit by engine from	"	60°·0*
Wheal Darlington **(Slate).**		
Large, out of rock	45·	57°·0
" " *north lode*	"	59°·0
" " " both sides	50·	57°·0
" " rock, 4 fms. S. of *lode*	"	59°·0
" " " 9 " "	"	58°·5
" " " 11 " "	"	58°·0
" " " 14 " "	"	57°·0
" " *south lode*, back	60·	62°·0
" " *north lode*, "	70·	64°·0
" " *elvan*, N. *wall*	80·	66°·0
" " *north lode* (salt water)	90·	64°·0
" " *cross-course* "	"	64°·0
Marazion Mines **(Slate).**		
Moderate, out of *lode*, end, E.	37·	56°·5
Large, " " W.	50·	58°·5
" " " E.	60·	59°·5
" " " W.	"	62°·0
" " " "	80·	63°·5
Small, " " E.	100·	66°·0
Drawn to adit by engine *(Rodney)* from	60·	60°·5*
" " *(Wheal Maid)* from	80·	68°·0*
" " *(Whl. Virgin)* "	100·	64°·0*
Retallack **(Slate).**		
Small, from *lode*, end, W.	33·	59°·5
Collected in bottom of the level	43·	63°·0
" "	53·	63°·0
South Wheal Neptune **(Slate).**		
Small, out of *lode*, back, E.	30·	61°·0
Drawn to adit by engine from (water salt)	"	56°·75*

THE GWINEAR DISTRICT.[1]

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Kayle **(Slate).**		
Small, out of *lode*, two spots in bottom	34·	59°·5
Herland **(Slate).**		
Very large, out of *Silver cross-course*	152·	77°·0
Small, " *Manor* "	"	81°·0
Drawn to adit by *(Fancy)* engine from	"	66°·0*
Wheal Alfred **(Slate).**		
Mud in bottom of level from which water had just been drawn	155.	64°·0
	"	65°·0
Carzise Consols **(Slate).**		
Large, out of rock, N. *wall*	75·	68°·0
" " *lode*, end, E.	85·	66°·0
Drawn to adit by engine from	"	63°·0*
Binner Downs **(Slate).**		
Small, out of *north lode*, back	50·	56°·5
" " "	96·	65°·5
" " *south lode*, "	126·	67°·0
" " rock, N. *wall*, two streams	136·	65°·0
Moderate, out of *north branch*, end, W.	156·	74°·5
" " *south lode*, " E.	166·	76°·0
" " *north branch* " W.	176·	82°·0
Large, jetting out of *south lode*, " E.	186·	82°·5
" out of " bottom	"	83°·0
Very large indeed, jetting out of *south lode*, end, W.	"	86°·5
Wheal Strawberry (Julia) **(Slate).**		
Small, out of *lode*, end, W.	70·	60°·0
" " " E.	"	60°·0
" " " "	79·	61°·5
Duffield (Weeth) **(Slate).**		
Moderate, out of *lode*, S. part	98·	63°·0
" " N. "	"	64°·5
Drawn to adit by engine from	"	61°·2*
Godolphin **(Slate).**		
Small, out of *lode*, back	20·	53°·0
" " *Orchard lode*, end, W.	30·	59°·0
" " *Pearce's lode* " "	50·	58°·0
" " rock, near *Pearce's lode*	"	58°·0
" " *Pearce's lode*, end, W.	70·	65°·0
" " bottom of *Pearce's shaft*	80·	66°·0
" " *Sims's lode*, end, W.	"	64°·0
" " " " E.	90·	66°·0
" " " " W.	"	68°·0
Large, " " bottom of shaft	92·	70°·0
Drawn to surface by engine from	"	67°·0*

1 Observations on the temperature of *Wheal Abraham*, *Crenver*, *Oatfield*, *Trenoweth*, *Wheal Alfred*, *Herland*, and *Relistian* are detailed by Mr. Thomas Lean, Mr. R. W. Fox, Dr. Forbes, and Mr. M. P. Moyle; Phil. Mag., xliii. p. 204; Cornwall Geo. Trans., ii. pp. 14-191-407-408-410-411-412; ibid. iii. pp. 317-323.

THE HELSTON DISTRICT.[1]

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Great Work **(Granite).**		
Small, from *Wheal Breage lode*, back	96·	62°·5
" " end, W.	132·	64°·0
" " "	142·	64°·5
" " *Great Work lode*, back	"	64°·5
Polladras Downs **(Slate).**		
Small, from *Bor lode*, end, E.	73·	61°·0
" " *Bissa lode*, "	83·	64°·0
" " *Bor lode*, end, W.	93·	63°·5
Large, " " E.	103·	66°·0
" " " "	113·	64°·5
Well at surface, between Trew and *Wheal Vor* (in slate), 1838, June 13th	—	51°·0*
" July 18th	—	48°·0*
Wheal Vor,—		
Carleen **(Granite).**		
Small, out of *lode*, end, W.	28·	52°·0
" " " E.	128·	66°·0
" " "	138·	68°·0
" " "	148·	69°·0
Drawn to adit by engine from	"	59°·0*
Eastern part **(Slate).**		
Small, out of *lode*, back	190·	68°·5
Large, " E.	230·	78°·0
" " "	240·	81°·0
" out of a hole between *lode* and rock, E.	"	80°·5
Drawn to adit by engines from	"	69°·0*
Wheal Trewavas **(Granite).**		
Small, out of *Way Sowan lode*	43·	61°·0
Large, " rock near *lode*	"	61°·0
" " *south lode*, end, E. (salt)	60·	57°·0
Drawn to adit by engine from	"	56°·0*
Wheal Trannack **(Granite).**		
Moderate, out of *lode*, end, W.	74·	64°·5
Wheal Trumpet **(Granite).**		
Small, oozing from *lode*	128·	65°·0[2]
" out of *lode*, back, W.	148·	68°·5
Wheal Ann **(Granite).**		
Small, out of *lode*, E.	12·	52°·5
" jetting out of *lode*, E.	142·	67°·0
Drawn to adit by engine from	"	59°·0*

1 On the temperature of *Wheal Vor, Wheal Trumpet, Trevenen*, and *Wheal Rose*, observations by Dr. Forbes, Mr. M. P. Moyle, Dr. Barham, and Mr. R. W. Fox, appear in the Corn. Geo. Trans., ii. pp. 185-406-411; ibid, iii. pp. 151-318; Phil. Trans. (1830), p. 407.

2 This observation made by me was first published by Mr. R. W. Fox, Corn. Geo. Trans., iii. p. 318.

THE CAMBORNE DISTRICT.[1]

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Stray Park (Slate).		
Small, out of *lode*, back of end, W.	188·	73°·5
Dolcoath (Slate).		
Small, out of rock	17·	54°·0
Cook's-kitchen (Granite).		
Drawn to adit by engine from	131·	60°·75*
There is water 65 fathoms deep in the bottom of the mine.		
Tincroft (Granite and Slate).		
Large, out of *cross-course*, S. (granite)	26·	52°·2
Small, collected in bottom of level, *Highburrow lode* (slate)	166·	65°·0
South Roskear (Slate).		
Moderate, jetting out of *lode*	117·	62°·0
Small, "	129·	68°·0
" out of *lode*	139·	71°·0
Drawn to adit by engine from	"	63°·0*
North Roskear (Slate).		
Small, out of *lode*, back	67·	61°·0
" jetting out of *lode*, end, E.	107·	66°·0
" out of *lode*, "	137·	73°·0
" " end, W.	"	70°·0
Drawn to adit by *Wheal Crofty* engine from	76·	61°·0*
East Wheal Crofty (Slate).		
Small, out of *Trevenson lode*	80·	61°·0
" " rock, 20 fms. N. of *lode*	"	62°·0
" " *Cherry Garden lode*, back	"	63°·75
" " " end, W.	"	62°·0
" " *Longclose engine lode*	85·	63°·5
" " " water in a hole in *lode*,	"	64°·25
" " " back of level	"	66°·0
" " " end	"	60°·0
This observation was made two years after the three preceding it and after the mine had been sunk 30 fathoms deeper.		
Small, out of *Fane's lode*, end	86·	57°·0
" " *Reeve's lode*,	110·	68°·5
" " "	115·	69°·0
" " " two years after the preceding, the mine having in the interval been sunk 30 fms. deeper	"	62°·0
Small, out of rock, W.	126·	66°·5
" " N. *wall*	135·	70°·75
Drawn to adit by engine from	150·	58°·5*
East Pool (Slate).		
Large, out of *lode*, back, E.	62·	59°·0
" " *cross-course*, near the *lode*	"	58°·5

1 The temperatures in *Stray Park*, *Dolcoath*, *Cook's-kitchen*, *Tincroft*, and *Wheal Wellington* have been observed by Mr. R. W. Fox and Dr. Forbes, Corn. Geo. Trans., ii. pp, 14-30-189; ibid, iii. 318.

CAMBORNE DISTRICT *continued.*

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Cairn Brea Mines (Granite).		
Large, out of *lode*, end, E.	121·	60°·75
" " rock, near *lode*	"	61°·75
Very large, jetting out of *cross-course*	151·	63°·0
Drawn to adit by engine from	"	63°·5*
Bisleak-well (in granite), at surface, about 420 ft. above the sea	—	52°·0*
Camborne-beacon (granite), " " 520 " "	—	49°·0*
Cairn-Brea-well (in granite), near the Castle, about 680 feet above the sea	—	48°·0*
THE REDRUTH DISTRICT.[1]		
Wheal Uny (Slate).		
Large, out of *lode*, W.	65·	58°·3
Very large, " E.	72·	59°·0
Large, out of rock, S.	"	60°·0
Small " *lode*, back	81·	61°·5
Wheal Buller (Slate).		
Small, out of rock, two spots	29·	52°·8
" " " "	"	52°·8
" " *cross-course*	"	52°·8
" " *Wheal Beauchamp lode*	49·	54°·0
Large, " "	59·	55°·5
Small, " rock, W.	79·	59°·3
" " *Davey's lode*, end, W.	89·	60°·5
" " " 6 feet from end	"	59°·5
" " rock *(elvan)*	99·	61°·0
Drawn to adit by *Wheal Buller* engine from	"	59°·0*
" *Wheal Beauchamp* engine from	"	58°·0*
Tresavean (Granite).		
Small, out of *lode*, end, E.	240·	78°·0
" " "	252·	79°·75
" " issuing very irregularly	264·	83°·0
" " end, E.	"	85°·0
" out of rock, N. *wall*	"	84°·5
Air, in bottom of a *winze*	"	86°·0*
Wheal Vyvyan (Granite).		
Small, out of rock	22·	52°·0
" " *lode*	77·	55°·5
Drawn by engine from	32·	51°·0
"	42·	52°·6
"	52·	52°·6
"	62·	54°·6
"	77·	55°·0

1 In the Corn. Geo. Trans., ii. pp. 14-20-405; ibid, iii. pp. 314-315-317; Phil. Trans. (1830), p. 407; and Reports of the British Association, vi. pp. 136-137, will be found observations by Mr. R. W. Fox, Mr. M. P. Moyle, and myself, on the temperatures of *Treskerby*, *Chacewater*, *Wheal Gorland*, *Wheal Unity Wood*, *Creegbrawse*, *Wheal Unity*, *Poldice*, the *United* and *Consolidated Mines*, *Ting Tang*, *Wheal Squire*, *Tresavean*, *Wheal Damsel*, and of the water discharged by the great adit into Carnon Valley.

REDRUTH DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Pennance (Slate).		
Drawn to surface by engine from	20·	56°·0*
Cardrew Downs (Slate).		
Moderate, out of *lode*, end	120·	64°·5
Chacewater Mine (Slate).		
Large, out of *lode*, end, E.	128·	75°·0[1]
Small, ,, ,, W.	,,	68°·0[1]
,, ,, rock	,,	72°·0
Poldice (Slate).		
Small, out of *lode*, end, W.	184·	100°·0[2]
,, ,, ,, E.	,,	99°·0[2]
Wheal Jewel (Granite).		
Small, out of *lode*, end, W.	90·	64°·0
East Wheal Damsel (Granite).		
Small, jetting out of *north lode*, end, W.	110·	63°·0
,, out of *north lode*, ,,	150·	71°·5
,, ,, *south lode*, ,, E.	,,	68°·0
Drawn to adit by engine from	180·	64°·0*
Consolidated Mines (Slate),—		
(*Western district, West Wheal Virgin*).		
Air, at end of level (Monday Morning)	204·	86°·0*
Moderate, out of *Taylor's lode*, end, W.	284·	89°·0
,, ,, back, E.	,,	89°·5
Large, ,, end, E.	294·	93°·5
,, ,, ,, W.	,,	92°·5
Air, at end, E., on *Taylor's lode*	,,	96°·0*
,, W., ,,	,,	94°·0*
Moderate, out of *south branch*, bottom	,,	95°·5
,, ,, back	,,	93°·5
Water collected at bottom of *Davey's* engine-shaft	,,	92°·5[3]
(*Middle district, East Wheal Virgin*).		
Air, at end, E. *Wheal Fortune lode*	250·	87°·0*
Large, out of ,, end, E.	,,	86°·5
,, ,, *Deeble's branch*	287·	94°·0
,, ,, rock, between *Deeble's branch* & *Wh. Fortune lode*	,,	94°·5
,, ,, *Wheal Fortune lode*	,,	93°·0
Air, at end of level, W.	,,	94°·0*
Small, out of vein, S. of *Wheal Fortune lode*	,,	92°·0
,, ,, hole in rock, near the *lode*	,,	91°·0
,, ,, ,, 20 fms. S. of *lode*	,,	92°·0
Water collected at bottom of *Pearce's* engine shaft	,,	91°·0[3]
,, drawn to adit by *Pearce's* engine from	,,	77°·5*

1 These observations made by me were published by Mr. R. W. Fox, Corn. Geo. Trans., iii. p. 317.

2 These observations made by me were published by Mr. R. W. Fox, Phil. Trans. (1830), p. 408.

3 In this water the labourers at the bottom of the mine plunge to *cool* themselves.

REDRUTH DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
(Wheal Fortune).		
Air, at end of level	185·	83°·0*
Moderate, out of *lode*, back of end, E.	195·	81°·5
Small, jetting out of *lode*, end, W.	205·	85°·0
Very large, ,, ,,	215·	88°·0
Large, ,, back	,,	86°·5
Air, at end of level, 5 fms. from shaft	,,	86°·5*
(Cusvey).		
Large, out of *lode*, end, E.	153·	68°·0
Small, ,, back of end, W.	173·	70°·5
***United Mines* (Slate),—**		
(Eastern part, Ale and Cakes).		
Very large, out of *Great south lode*	170·	67°·0
Small, ,, a hole 8 ins. deep in rock	,,	82°·0
Moderate, ,, *Great south lode*, N. part	180·	82°·0
,, ,, ,, S. ,,	,,	83°·0
Very large ,, *cross-course*	,,	74°·0
Small, ,, rock, 2 feet from last obs.	,,	77°·0
Moderate, ,, *Great south lode*, S. part	195·	84°·75
,, ,, rock, close to *lode*	,,	86°·5
,, ,, ,, between *Gt. south lode* and *Old lode*,	,,	93°·5
Large, ,, *Old lode*, end, W.	,,	83°·5
,, ,, ,, ,, E.	,,	88°·0
Air, at end, *Old lode*, end, E.	,,	91°·0*
,, at bottom of engine shaft	210·	79°·0*
,, in *cross-cut*, N. of shaft	,,	87°·0*
Moderate, out of *Great south lode*, end, E.	,,	89°·5
,, ,, rock, ,,	,,	92°·0
,, ,, ,, 3 feet from last	,,	92°·75
,, ,, *Great south lode*, end, W.	,,	84°·0
,, ,, a small vein	,,	92°·0
Drawn to adit by engines from	,,	76°·5*
(Western part, Poldory).		
Moderate, out of *Mundic lode*, W.	148·	72°·0
,, ,, rock, N. of *Old lode*	,,	80°·0
,, ,, ,, S. ,,	160·	80°·0
,, ,, *Old lode*	,,	80°·0
,, ,, ,, end, E.	173·	85°·0
,, ,, ,, 2 feet from last obs.	,,	86°·0
,, ,, joint in rock	,,	76°·5
,, ,, ,, 6 feet from last obs.	,,	78°·0
Large, out of joints in *elvan*, all within the space of 12 feet, and all portions of the same sheet of water gushing out	184·	90°·0 89°·5 88°·0
Drawn to adit by engine from	,,	75°·0*
Well at *Wheal Fortune*, (surface) 1840, January 1st	—	49°·5*

REDRUTH DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.

Temperature of the water discharged into Carnon Valley by the great adit of the Gwennap mining district: and of a well, and the river near its mouth.*—

	River.[1]	Ferney Splat, well, surface, 4 ft. from adit.	Great adit.[2]	Nangiles adit.
1839				
Jan. 2,	51°·0	53°·0	63°·4	61°·5
March 8,	48°·5	50°·3	63°·2	60°·0
July 16,	71°·75	—	66°·5	—
1840				
Jan. 1,	52°·0	52°·25	60°·5	59°·25
27,	48°·0	51°·5	60°·5	60°·0
March 9,	57°·0	—	65°·0	61°·0
31,	73°·5	—	66°·5	62°·75
April 16,	64°·0	—	68°·0	59°·75
1842				
Dec. 30,	53°·5	53°·0	64°·5	61°·0

THE SAINT AGNES DISTRICT.[3]

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Towan (Slate).		
Moderate, out of *lode*	108·	62°·0
Collected from 73 fms. to	124·	67°·5
Small, out of *lode* (a gurgling noise, as of air escaping, occurs in this stream)	134·	69°·5
„ „ end, E.	„	72°·5
„ out of rock, back of end, W	„	70°·0
„ „ *lode*, end, W.	144·	70°·0
„ jetting out of *lode*, end, E.	„	74°·75
„ „ „ W.	154·	72°·0
„ out of *lode*, „ E.	„	72°·5
East Wheal Charlotte (Slate).		
Small, out of rock	42·	59°·0
Penwinnick (Slate).		
Large, jetting out of *lode*, end, W.	32·	57°·5
„ out of *lode*, back, W.	42·	59°·0
West Pink (Slate).		
Small, out of *lode*, end, W.	70·	60°·0
Drawn to adit by engine from	90·	61°·5*

1 On the 27th of June, at One p.m., I examined the temperature of the river immediately above the *Falls of Niagara*, and found it 68°, that of the air being 69°. At Eight p.m., the same day, the surface of the water in Lake Ontario, a mile from the shore, was at 47°·75, the air being at 67°.

2 Mr. R. W. Fox (Corn. Geo. Trans., iii. p. 316) states that in 1822 the temperature of the water discharged by this adit was 69°·25, but he has not mentioned at what period of the year the observation was made.

3 The temperature in *South Wheal Towan* has been recorded by Mr. R. W. Fox, Corn. Geo. Trans., iii. p. 314.

SAINT AGNES DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Prudence (Slate).		
Large, out of *lode*, end, W.	100·	65°·5
Wheal Leisure (Slate).		
Moderate, out of rock, S. *wall*	86·	69°·0
Small, "	96·	72°·0
Large, out of *lode*, ...	"	69°·0
Wheal Budnick (Slate).		
Moderate, out of rock, W. *wall*	64·	59°·0
" " E. *wall*, near end	"	60°·0
" " " 10 fms. from last obs. ..	"	60°·4
" " " 10 fms. from last obs. ..	"	61°·2
" out of *Lead lode*	74·	63°·5
Drawn to adit by engine from	"	60°·0*
THE SAINT AUSTELL DISTRICT.		
Polgooth (Slate).		
Drawn to surface by engine from	32·	55°·5*
Charlestown United Mines (Slate).		
Small, out of rock, S. of *lode*	52·	55°·0
Pembroke (Slate).		
Small, out of *lode*, end, W.	120·	72°·0
Drawn to surface by engine from	"	57°·5*
East Crennis (Slate).		
Large, out of *south lode*, end, W.	102·	70°·0
Fowey Consols Mines (Slate).		
Small, out of *Crosspark lode*, back	160·	67°·0
" " " end	"	68°·5
Large, " *cross-course*, back	220·	87°·0
" " " end, N.	"	90°·5
THE CALLINGTON AND TAVISTOCK DISTRICT.[1]		
Redmoor Consols Mines (Slate).		
Small, out of rock	18·	54°·0
Drawn to adit by engine from	30·	57°·0*
Wheal Franco (Slate).		
Large, out of *lode*, end, W.	60·	63°·5
Drawn to adit by engine from	"	60°·0*

1 In this district the temperatures of *Wheal Friendship, Beeralston, East Liscombe*, and *Gunnis Lake* have been recorded by Mr. R. W. Fox, Corn. Geo. Trans.. iii. pp. 314–321.

CALLINGTON AND TAVISTOCK DISTRICT continued.

Name of Mine, Rock, Appearance of Stream, and Locality of observation.	Depth fms.	Temp.
Wheal Friendship (Slate).		
Moderate, out of *eastern cross-course*	47·	55°·0
Large, „ *cross-course*, two streams, both	75·	54°·0
Moderate, „ „	115·	64°·0
„ „ „ 6 ins. from last obs. ..	„	65°·5
„ „ rock, W.	„	64°·0
Large, out of *lode*	„	60°·0
„ „ 6 ins. from last obs.	„	62°·0
Small, „	135·	69°·5
Drawn to surface by engines from	„	62°·0*
Wheal Calmady (Slate).		
Moderate, out of *cross-vein*, end, S.	24·	54°·0
Drawn to surface by engine from	„	58°·5*
Well at Roborough Down, surface (slate)	—	49°·0*

The foregoing materials furnish the means of comparing the temperatures at similar depths, in the different districts;—in the different rock formations;—in the *lodes* yielding different ores;—and in the rocks, *lodes*, and *cross-veins*.

The following table presents a comparison of the temperatures prevailing at nearly similar depths, in the different districts, in which the mines of Cornwall and Devon seem naturally grouped:—

TABLE II.

Districts.	Surface to 50 fms.		50 to 100 fms.		100 to 150 fms.		150 to 200 fms.		200 fms. & beyond		Means	
	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.
Saint Just	25·	51°·45	70·	56°·17	128·	62°·75	156·	61°·01	—	—	95·	57°·84
Saint Ives	28·	54°·16	73·	59°·64	119·	67°·0	197·	65°·01	228·	72°·01	129·	63°·56
Marazion	33·	58°·62	64·	61°·66	131·	71°·33	—	—	—	—	76·	63°·87
Gwinear, &c. ..	28·	57°·1	78·	63°·53	131·	66°·0	167·	76°·0	—	—	101·	63°·4
Helston	31·	56°·6	80·	62°·1	133·	66°·1	190·	68°·5	237·	80°·01	134·	66°·66
Camborne, &c.	21·	53°·3	78·	61°·5	125·	66°·54	168·	67°·17	—	—	98·	62°·13
Redruth, &c. ..	33·	52°·7	76·	58°·3	130·	70°·64	177·	86°·07	245·	89°·17	132·	71°·37
Saint Agnes ...	39·	58°·5	75·	63°·9	129·	69°·0	154·	72°·25	—	—	99·	65°·91
Saint Austell ..	—	—	52·	55°·01	111·	71°·0	160·	67°·75	220.	88°·75[1]	136·	70°·62
Tavistock, &c. .	30·	54°·3	67·	58°·75	118·	64°·16	—	—	—	—	72·	59°·07
Means....	30·	54°·87	72·	60°·88	127·	67°·43	173·	78°·0	240·	85°·52	112·	66°·88

1 From single observations only.

TABLE III.

Mean temperatures at nearly equal depths in the granite and slate rocks.

Depths.	Granite.		Slate.	
	Depth fms.	Temp.	Depth fms.	Temp.
Surface to 50 fms.	25·	52°·67	30·	55°·9
50 to 100 fms.	71·	57°·68	73·	61°·9
100 „ 150 „	132·	65°·0	125·	68°·14
150 „ 200 „	161·	65°·7[1]	174·	79°·17
200 fms. and beyond	240·	76°·15	241·	89°·4
Means	94·	60°·35	116·	68°·89

1 From five observations only.

TABLE IV.

Mean temperatures of the rocks, *cross-veins*, and *lodes*, at nearly equal depths.

Depths.	Rocks.		*Cross-veins.*		*Lodes.*	
	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.
Surface to 50 fms.	32·	55°·52	31·	53°·76	29·	54°·83
50 to 100 fms.	70·	60°·2	76·	61°·2	71·	59°·87
100 „ 150 „	134·	69°·66	115·	64°·75[1]	126·	66°·88
150 „ 200 „	180·	82°·11	163·	74°·4	161·	72°·41
200 fms. and beyond	235·	87°·9	220·	88°·75[1]	246·	88°·57
Means	111·	67°·55	99·	64°·82	111·	66°·04

1 From only two observations.

TABLE V.

Mean temperatures, at nearly equal depths, in the *lodes* which contain ores of different metals.

Depths.	Tin *lodes*.		*Lodes* yielding both tin & copper ores.		Copper *lodes*.	
	Depth fms.	Temp.	Depth fms.	Temp.	Depth fms.	Temp.
Surface to 50 fms.	27·	53°·14	33·	55°·06	32·	56°·9
50 to 100 fms.	71·	59°·15	72·	61°·16	74·	61°·8
100 ,, 150 ,, ...	129·	65°·92	124·	66°·09	127·	68°·39
150 ,, 200 ,, ...	181·	64°·83[1]	171·	81°·75[2]	172·	78°·33
200 fms. and beyond	230·	74°·3	—	—	244·	89°·14
Means	92·	60°·69	74·	61°·45	140·	72°·39

1 From three observations only. 2 From four observations.

The following table indicates the respective ratios of increase in temperature, expressed in fathoms of descent requisite to produce an elevation of one degree. The columns 2 and 3 are formed from Table III.; 4, 5, and 6 from Table IV.; 7, 8, and 9 from Table V.; and the last is the arithmetical mean of all the others. The eight columns are therefore deduced from the same facts, grouped in three different ways: it may therefore be anticipated that there will be considerable resemblance,—between some of them, at least.

The temperature of the air at Plymouth and Penzance, which are near the eastern and western limits of the mining districts of Devon and Cornwall, has been very accurately[3] determined: and the

[3] The mean temperature of Plymouth is stated, by Mr. Harris, at 52°·081; Reports of the British Association, vii. p. 24: that of Penzance, at 52°·0, by Mr. Giddy, Phil. Mag. and Annals, iii. p. 182.

observations made at several intermediate spots[1] may, perhaps, be equally relied on.

But this temperature, though affecting the rock to the depth of several feet,[2] cannot extend its influence very far; and, consequently, the observations made upon it will not, perhaps, avail much in the present enquiry.

No experiments have been made in Cornwall to determine at what depths, in different soils and rocks, at various periods of the year, the effects of atmospheric temperature cease, and those of subterranean heat commence.

Mr. R. W. Fox's observations[3] on the temperature at the depth of a few feet, are the only ones here with which I am acquainted: and, because in many of the wells and shallower parts of the mines which I have

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1 Observations on the temperature of Truro are recorded in the Reports of the Royal Institution of Cornwall: and of Falmouth, in the Reports of the Royal Cornwall Polytechnic Society.

2 Professor Forbes, from observations made in the neighbourhood of Edinburgh, states, on the average of three years' experiment, that the effects of atmospheric temperature will become insensible at the following depths, in different substances:—

Trap rock	55·5 feet.
Sand	65·8 „
Sandstone	96·1 „

Reports of the Brit. Assoc. (1840), p. 435.

At Paris the effects of atmospheric temperature ceased at 25 feet; whilst in various Prussian mining establishments it was found to extend to depths varying from 27 to 63 feet.

Professor Bischoff, Edin. New Phil. Journal, xxiii. (1837), p. 341.

3 The bulbs of the thermometers were sunk to a depth of three feet below the surface, and the mean annual temperatures observed were,—

At Wheal Gorland (granite)	48°·09
„ Dolcoath (slate)	49°·94
„ Falmouth (slate)	50°·67
Mean	49°·86

Mr. R. W. Fox, Corn. Geo. Trans., iii. p. 326.

examined (Table i.), I have obtained the same average, viz. about 50 degrees, I concur with him[1] in thinking that we may begin our computations at that temperature; and I have, accordingly, taken it as my point of departure.

TABLE VI.

Depths.	Granite.	Slate.	Rocks.	*Cross-veins.*	*Lodes.*	Tin *lodes.*	*Lodes* yielding both tin & copper ores.	Copper *lodes.*	Means.
	Fms.	Fms.	Fms.	Fms.	Fms.	Fms.	Fms.	Fms.	Fms.
Surface to 50 fms. ..	9·3	5·0	5·8	8·2	6·0	8·6	6·5	4·6	6·8
50 to 100 fms.	9·1	7 1	8·1	6·0	8·3	7·3	6·4	8·5	7·6
100 „ 150 „	8·3	8·3	6·7	11·0[3]	7·8	8·5	10·5	8·0	8·7
150 „ 200 „	—[2]	4·4	3·7	4·9	6·3	—[4]	3·0[5]	4·5	4·5
200 fms. and beyond,	7·5	6·5	9·5	3·9[3]	5·2	5·1	—	6·6	6·4
Means	8·5	6·2	6·7	6·8	6·7	7·3	6·6	6·4	6·8

2 Five observations only. 3 From two observations only. 4 From only three observations. 5 From four observations.

(1.) As the mining districts vary considerably in their geological characters, it might have been expected that the temperatures at equal depths would not exactly coincide in all. Of this inequality, which is very conspicuous in Table ii., it is not easy, and perhaps not possible, to give a satisfactory explanation. As the situations of the mines differ very much in their elevations, in very few instances do equal depths below the surface hold the same positions with regard to the sea level. This is probably

1 Corn. Geo. Trans., iii. p. 326, and Reports of Brit. Assoc. (1840), p. 310.

one cause of the observed irregularities in temperature: but it will presently be seen that there are others, which depend on the geological characters of the rocks and veins.

Table II. shows that the subterranean isothermal lines are not exactly parallel to the configuration of the surface; although, in many instances, there is a sort of distant resemblance in their outline.

Table I. presents many examples of different temperatures at equal depths; not only in the same mines, but even in various parts of the streams of water flowing out of the very same crevices and apertures, within a few feet, or even inches, of each other. It need, therefore, excite no surprize that there is not a perfect uniformity in the temperatures of tracts miles distant from each other.

(2.) No attempt to determine the difference between the mean temperature of the granite and slate, at various depths, was made before this enquiry had been considerably advanced;[1] although the fact had been alluded to,[2] and had been, from time immemorial, known to practical miners.[3]

This difference is exhibited in Table III., and is far more conspicuous in the deeper than in the shallower levels.

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1 My own Papers, Thomson's Records of General Science, iv. (1836), p. 198: Reports of the British Association, vi. (1837), p. 36.

2 Mr. R. W. Fox, Annals of Philosophy, iv. (1822), p. 447; Phil. Mag. and Annals, ix. (1831), p. 98.

3 "From observations carried on in various mining establishments in the "Prussian dominions, M. Von Dechen finds that the increase of temperature is, "in general, much more rapid in coal than in metalliferous mines."

PROF. BISCHOFF, *Edin. New Phil. Journal*, xxiv. (1838), p. 141.

The granitic rocks may be more exposed to the cooling influences of descending streams, as their structure permits the percolation of water more readily than that of the slate series.

(3.) The general impression has been that the temperature of the rocks is lower than that of the veins:[1] the results of my enquiries, however, conclusively demonstrate that, at all depths, the rocks are warmer than the *lodes*, and the *lodes* than the *cross-veins*.—(Table IV.)

It is well known to miners that the largest streams of water flow through the *cross-veins*;[2] smaller ones through the *lodes*; whilst but little issues from the rocks, whether granitic or slaty. It is an equally recognized fact, that a considerable portion of the water pumped out of our mines has been rain-water; which must have entered the ground at a temperature nearly the same as that of the atmosphere;—consequently much lower than that prevailing at even comparatively small depths in the mines.

It therefore is obvious, that as the *cross-veins* receive the largest quantity of this cold water, they will be most affected by its cooling influence;[3]

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1 Mr. R. W. Fox, Corn. Geo. Trans., ii. p. 21; Report of the Royal Corn. Polytech. Soc. (1836), p. 107: Dr. Forbes, Cornwall Geo. Trans., ii. p. 217: my own Summary of Experiments made in Cornwall (by other observers), Edin. Journal of Science x. o.s. (1829), p. 244.

2 As a general fact, the *cross-veins* traverse the *lodes*; and thus, by falling in contact with and separating all of them, become the main subterranean aqueducts or channels for the circulation of water.

3 At 264 fathoms deep, in Mr. Pemberton's Colliery, at Monk-Wearmouth, Professor Phillips found, that as bubbles of gas rose through the water its temperature fluctuated; in one case, from 69°·1 to 69°·7, and in another, from 71°·6 to 72°·6. Lond. and Edin. Phil. Mag., v. (1834), p. 449.

At 230 fathoms deep, in *Dolcoath*, Mr. R. W. Fox placed a long thermometer whilst, as the rocks absorb the smallest proportion of it, they will therefore suffer the least depression of temperature.

That this is one cause of the observed difference, can admit of no doubt;—whether it is the only one, is foreign to this enquiry.

It may be true that the ascent of vapour, which would tend to raise their temperature,[1] is facilitated by the more porous nature of the veins; but, on the other hand, it must not be forgotten, that this porous structure also affords a readier passage for the descending water.

(4.) The working miners of Cornwall have long known that the *lodes* containing tin ores are, at equal depths, colder than those in which copper ores occur. This has been noticed by Mr. M. P. Moyle:[2] but no attempt has, until now, been made to determine the exact difference between them.

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in the copper *lode;* and, unless overflowed by water, it for many months indicated a temperature varying only from 75°·0 to 75°·5.

Cornwall Geo. Trans., ii. p. 27.

But, in metalliferous districts, the constancy of the temperature of water issuing from the same spot, at distant periods, must depend on the subterranean works remaining unaltered: for, if the deeper levels are untouched, and the shallower ones are extended, the warm water from below will rise as before, whilst the cold from above will be intercepted, and thus the temperature of that flowing from intermediate spots will rise. If, on the other hand, the shafts are deepened and levels *driven* beneath, whilst the shallower ones are unwrought, the former will intercept the warm water and prevent its rising, and the cold water from above still flowing as before, the temperature of intermediate stations will decline.

Such, in fact, is the case at *East Wheal Crofty*, where the temperatures at two different spots, within two years, diminished,—the one 8°·0 to 7°·25, and the other 7°·0; both parts of the mine having in the interval been deepened 30 fathoms.

Whatever cause may increase the water from above, must lower the temperature; whilst any addition to that from below, must elevate it.

[1] Mr. R. W. Fox, Corn. Geo. Trans., ii. p. 16. [2] Ibid, ii. p. 414.

Table v. clearly proves the truth of this popular opinion: and indicates that the *tin-lodes* possess the lowest temperature,[1] and *copper-lodes* the highest; whilst the *lodes* in which the ores of both metals are mixed, hold, in this respect, an intermediate position.

(5.) The general fact of a progressive elevation of temperature as we penetrate further into the crust of the earth, naturally leads us to enquire the ratio of its increase.

The manner in which Table vi. is constructed has been already described; and as the ratios presented by the different varieties of rocks and veins are there exhibited connectedly and at one view, it is needless to dilate on them.

From the surface to 150 fathoms deep, the rise of temperature, for equal increments of depth, seems to be in a diminishing ratio:—a fact previously known.[2] But deeper observations disclose the curious, and as it would seem almost anamalous, circumstance, that at more than 150 fathoms deep the progression again becomes more rapid; and that the ratio at about 150 fathoms in depth is at a minimum, and increases, both at greater and smaller depths.

Whether further experiments may confirm or disprove the generality of this fact, I do not pretend even to conjecture: but I must remark that the

1 The same general fact is also known in Germany: for Professor Bischoff says,—"The tin mines of Sauberg at Ehrenfriedersdorf show a remarkably low "temperature: indeed it is a prevailing opinion there that stanniferous moun- "tains are colder than others. * * * The low temperature of Heinrichssohle "in the Altenberg district in the Erzgebirge, was also ascribable to the rocks "of tin-stone." *Edin. New Phil. Journal*, xxiv. (1838), p. 140.

2 Mr. R. W. Fox, Reports of the British Association (1840), p. 315.

number of observations I have made at more than 150 fathoms deep is very considerable.

The various ramifications of the great adit in the Gwennap mining district have an aggregate extent of between thirty and forty miles. It drains a tract of about 5,550 acres in area, and discharges nearly 1,600 cubic feet of water per minute. Rather less than one-half of this stream is collected at the adit level, whilst the remainder is pumped up from a mean depth of about 190 fathoms. Its temperature varies between 60°·5 and 68°·0, and is, on an average, more than 12° above the mean of the climate.

The subject of subterranean temperature attracted attention in France and Germany long before it did so in this country.[1] Though I have made some

[1] M. Daubuisson, des Mines de Freiberg, i. p. 258; ibid, iii. pp. 151–186–200: M. de Trebra, Annales des Mines, i. (1816), p. 377; ibid, iii. (1818, observations made 1805-7), p. 59: M. Hassenfratz, ibid, i. p. 378: M. Le Baron Cordier, Sur la Température de l'intérieur de la Terre, Memoires de l'Académie des Sciences, vii. (1827): M. J. Levallois, Annales des Mines, iii. (1833), p. 629: M. Reich, Beobachtungen ueber die Temperatur des Gesteins in verschiedenen Tiefen in den Gruben des Sachsischen Erzgebirges in den Jahren 1830 bi 1832: Prof. Bischoff, Edin. New Phil. Journal, xxiii. (1837), p. 330; ibid, xxiv. (1838), pp. 132–252.

NOTE *to page* 388, *line* 1.—" During his observations on the hourly variations " of the magnet, Reich had an opportunity of observing the rapidity with which " the air operates upon the rock even at a distance of 40 inches. The air in " the mine shewed 48°·6 with but slight variations, and a thermometer sunk " into the rock 48°·64; but when, after 44 hours' observation of the magnet, " the temperature of the air had been raised by the presence of the observers, " and their two candles, to 49°·7, the thermometer in the rock, which was sub- " ject to no change of air whatsoever, was found to have risen to 48°·71, " 48°·73. This destroyed all hope of obtaining the temperature of the rock, " quite free from the influence of the air, by sinking thermometers even 40 " inches deep into the rock."

PROFESSOR BISCHOFF, *Edin. New Phil. Journal*, xxiii. (1837), p. 342.

NOTE *to page* 407, *line* 7.—" A chthonisothermal line of any temperature, " which was under a small district parallel to the surface, cannot continue its " course under a neighbouring mountain, either parallel to the external configu- " ration of the mountain, or in the continuation of its former direction, but " must curve upwards." Ibid, xxiv. (1838), p. 146.

progress in a comparison of the results there observed with those obtained here, and such an enquiry would embrace many points of interest, I must defer its completion until a more convenient opportunity; as, in this communication, I have purposely confined myself to my own observations in Devon and Cornwall.

W. J. HENWOOD.

4, Clarence-street, Penzance,
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