British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Groundwater residence time in Malta

Marianne Stuart

With thanks to Manuel Sapiano, Miriam Micallef Sultana, Daren Gooddy, Louise Maurice, John Chilton, Tim Heaton and Peter Williams

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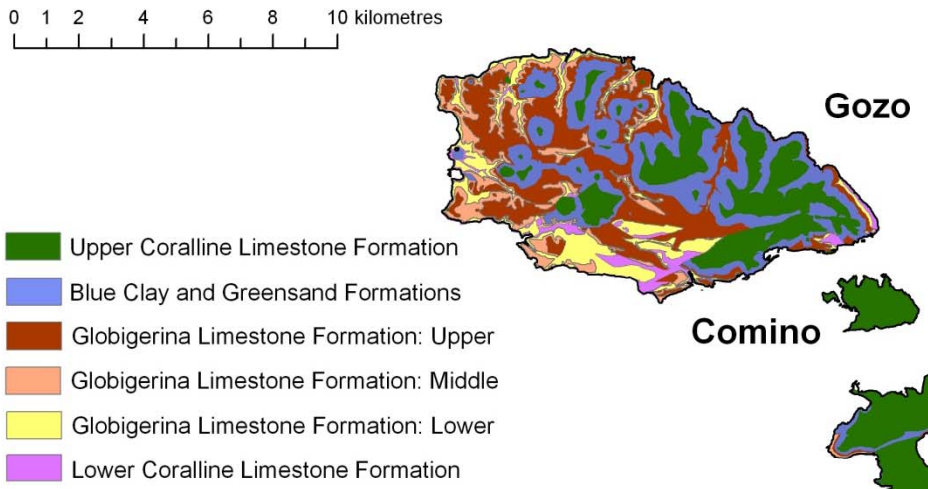
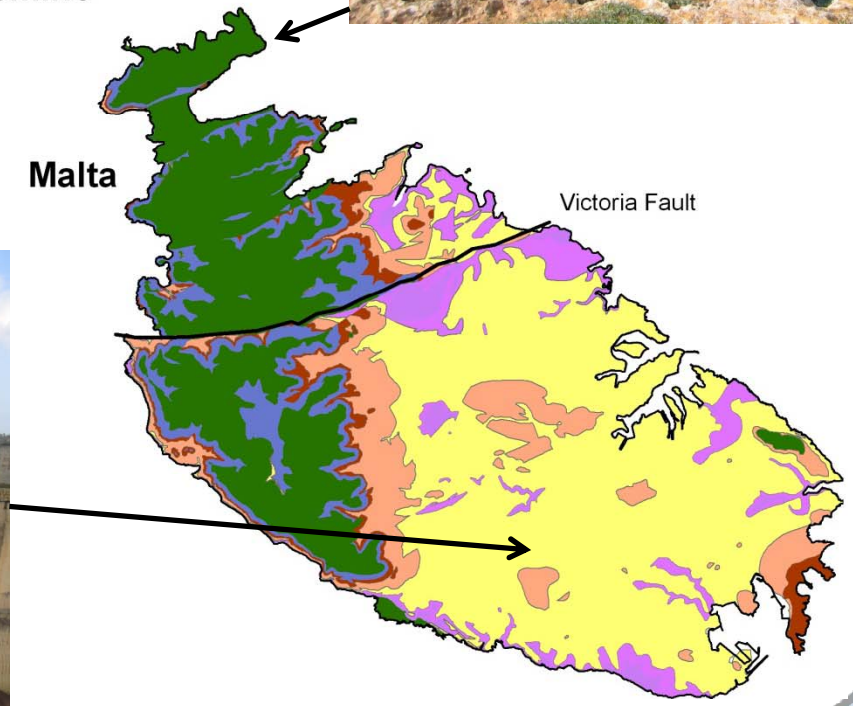
Malta: basic facts

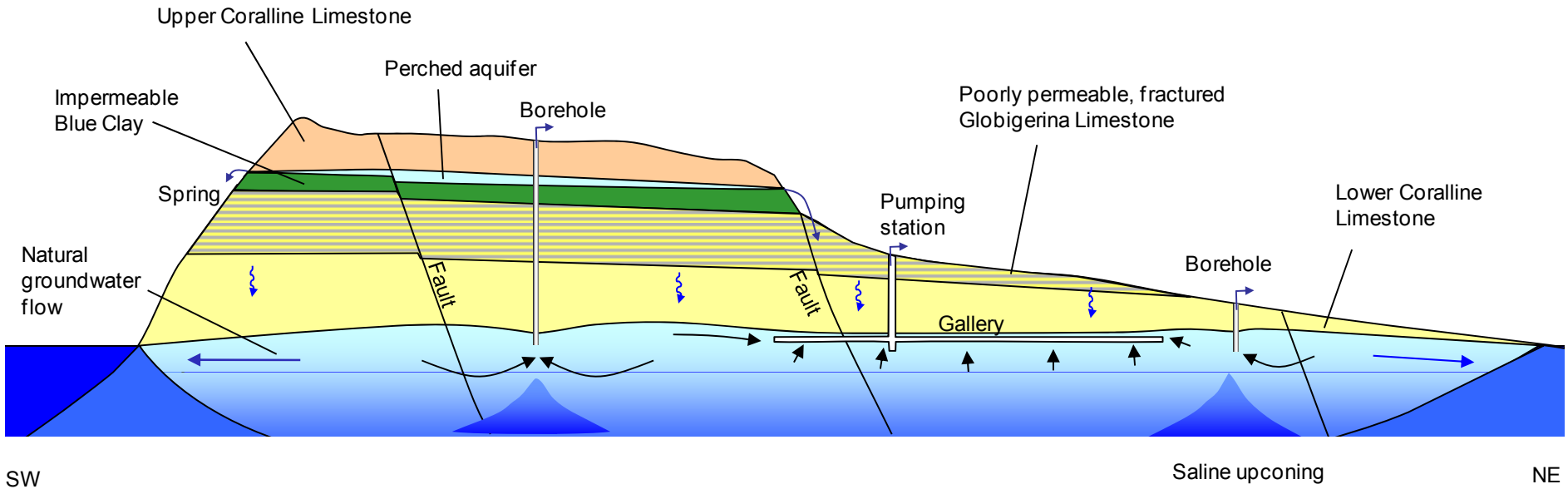
- Area 316 km^2
- Population 400k residents plus tourists
- >50% public supply from desalinated water
- 75k pigs, 20k cattle, 1 million poultry
- Main crops – fodder, vegetables and flowers, potatoes, vines and orchards

Geological setting





Conceptual cross-section



- Perched aquifers in Upper Coralline limestone supplying springs
- Sea level aquifers in Lower Coralline
- Water levels close to sea level due to pumping from boreholes and sea level galleries
- Saline upconing
- Gozo similar to western side but lower elevation

Hydrogeology

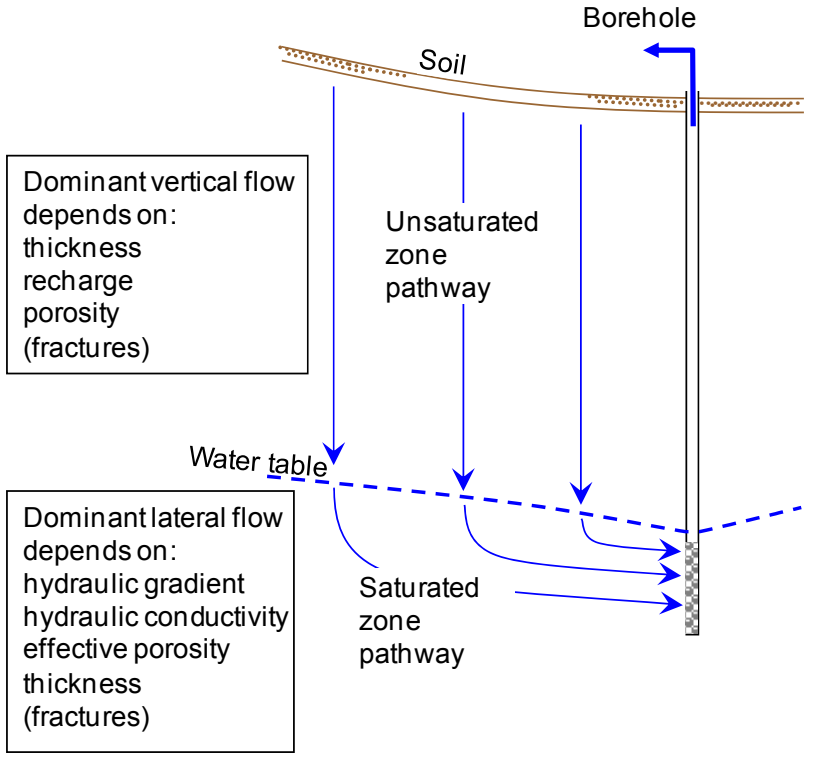
- Contrasts with many limestone islands:
  - low rainfall and high relief
  - complex hydrogeology with poorly permeable strata and perched aquifers
- Initially assumed to be rapidly responding karst limestone system:
  - surface karst features
  - enlarged fissures in quarry faces
  - rapid infiltration and water level response
  - reputedly ubiquitous coliforms
  - saturated nitrate varies spatially
- But some evidence of long residence time from:
  - relationship between volume of aquifer storage and annual recharge
  - tritium

Difficulties of dating water in island aquifers

- Understanding the flow regime
  – water levels heavily influenced by abstraction
- ^{14}C age indicator
  – compromised by carbonate dissolution
- Carbonate dissolution indicators (Mg, Sr and Li relative to Ca)
  – compromised by saline impact from coastal intrusion and upconing

Determining the groundwater flow regime

- Groundwater age indicators:
  - CFC and SF_6
  - Tritium
  - Coliforms
- Geochemical processes:
  - Water and carbon stable isotopes
- Controls:
  - Water balance
  - Aquifer properties – little available for Malta
  - Unsaturated zone thickness – up to 100 m
  - Semi-permeable capping of MSL aquifers
  - Controls on water levels – abstraction



Estimated water balance for 2002

Element of water balance		10^6 m^3/year
Inflow	Precipitation	174
	Surface run off to sea	-24
	Evapotranspiration	-105
	Recharge from leaks	12
	Net inflow	57
Outflow	Public supply abstraction	16
	Private abstraction	15
	Subsurface outflow to sea	23
	Total outflow	54
Balance		**3**
Total aquifer storage		1.5×10^9 m^3
Storage time (storage/inflow)		**~26 years**

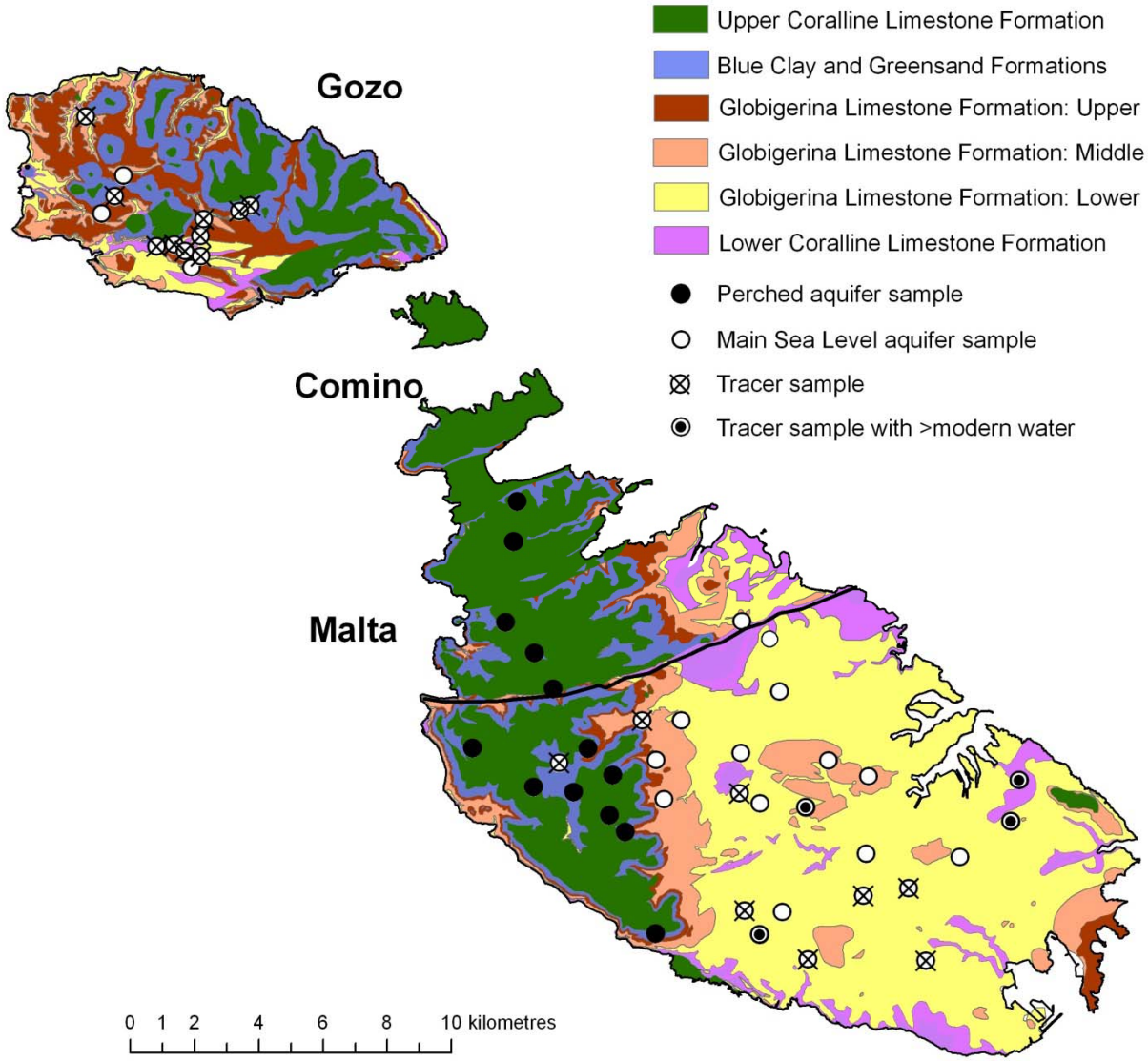
Aquifer properties

Parameter	UCL	Globigerina	LCL	Chalk	Jurassic Limestone
Primary porosity (%)	41 – 45	32 – 40	7 – 20	34	14.5 – 19.1
Effective porosity (%)			10 – 15		
Matrix permeability (m/d)	9×10^{-4}	9×10^{-3}	<UCL	6.3×10^{-4}	1×10^{-4} – 0.018
Aquifer hydraulic conductivity (m/d)			35		
Transmissivity (m^2/d)			8 – 86	410 – 1800	139 – 318
Travel time unsaturated zone (m/year)	**0.39 – 0.42**	**0.43 – 0.54**	**1.2 – 1.7**	**0.8-1***	**1.1***

* Value estimated from porewater profiles

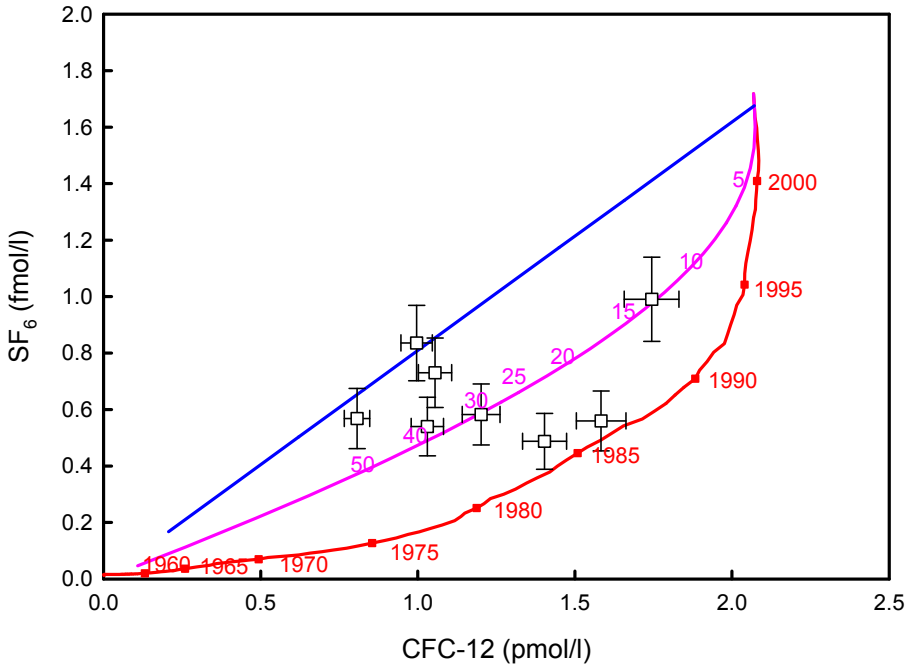
Groundwater sampling sites

Groundwater sampling sites and tracers



- 59 sites visited
- 12 in perched
- 24 in Malta MSL
- 14 in Gozo MSL
- 23 samples for tracers

Saturated zone age from CFCs & SF_6

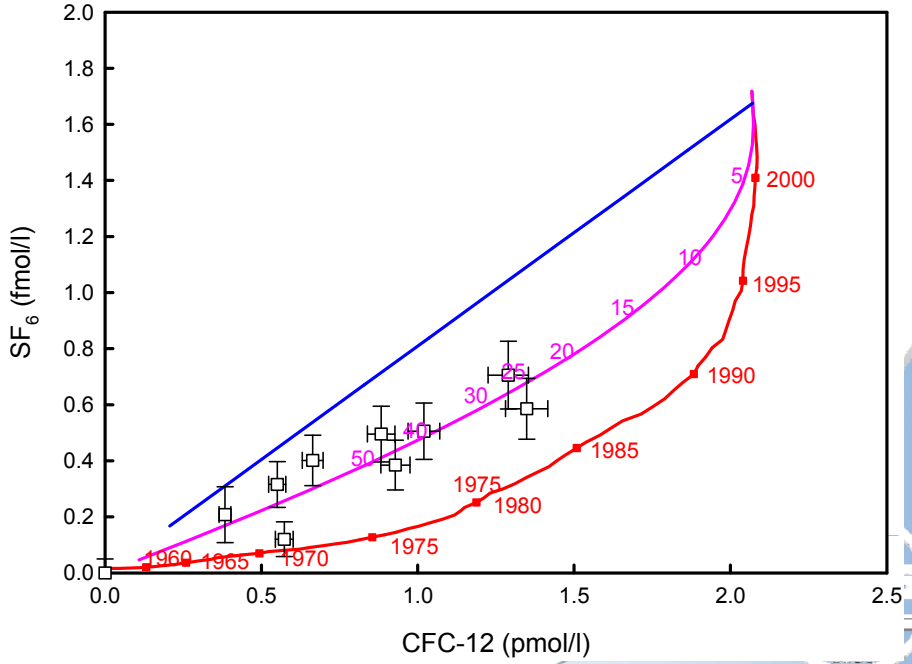


Malta MSL

Interpreted age 15-40 years

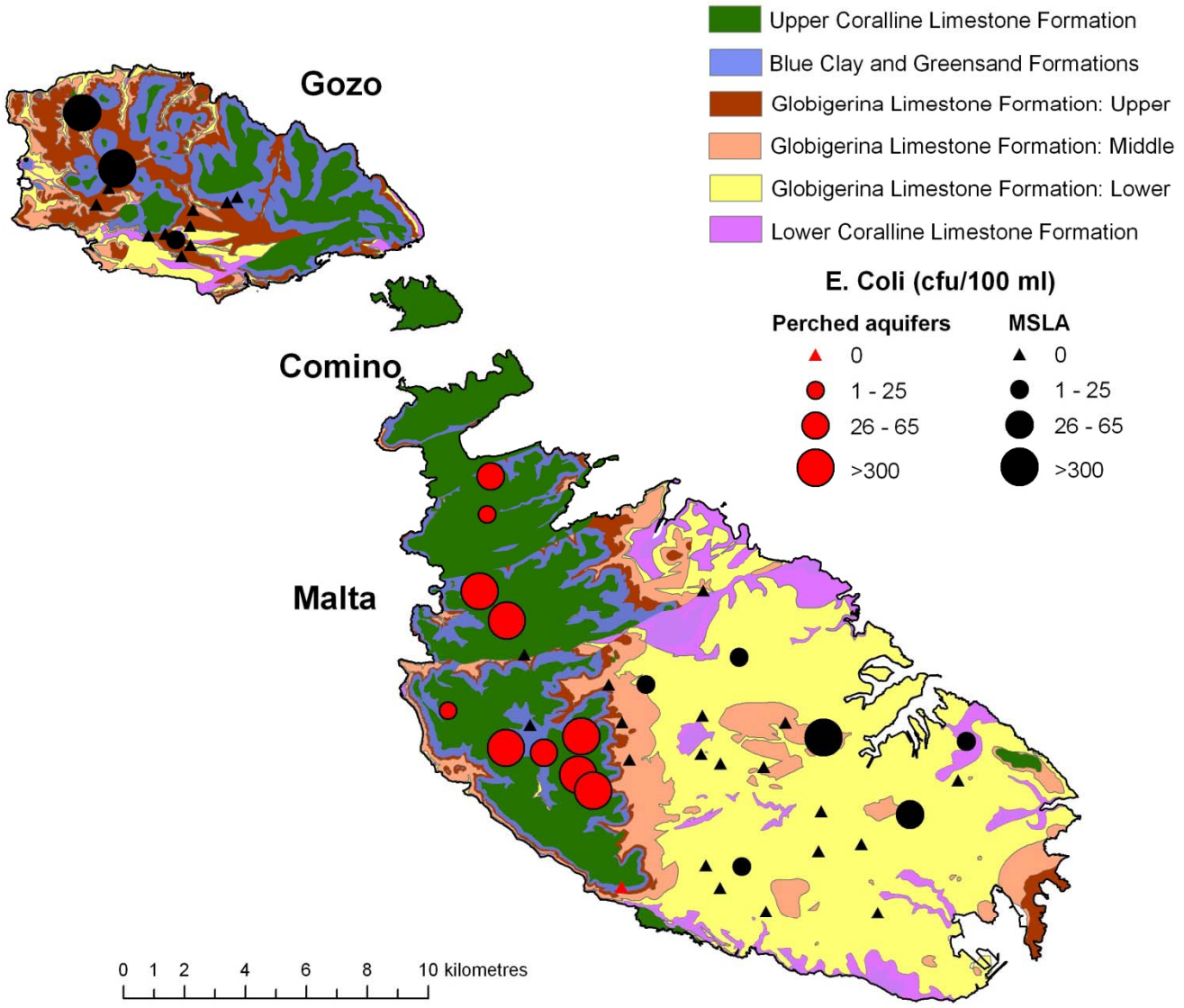
Gozo MSL

Interpreted age 25-60 years

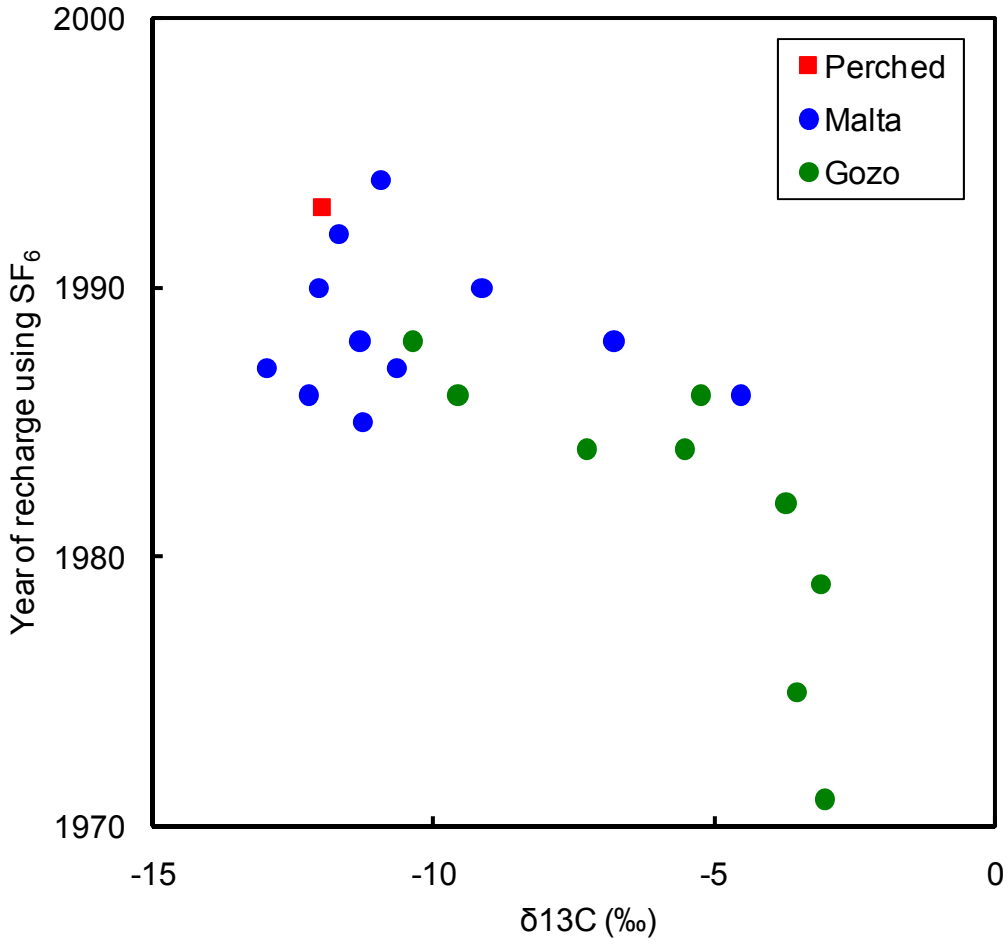


Tritium data suggested about 40 years in total

Detections of coliforms

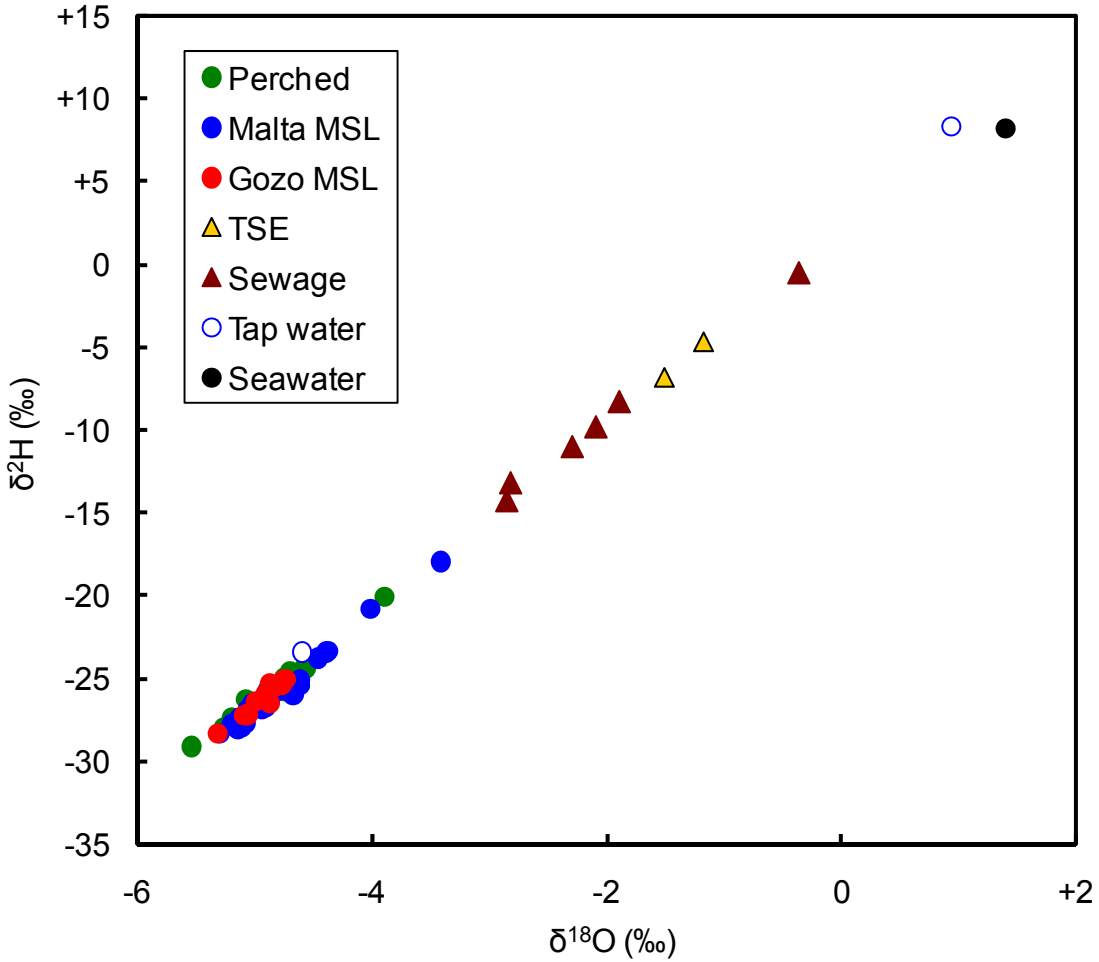


SF_6 age and $\delta^{13}C$



- Expect high $^{13}\delta C$ in much older waters
- May indicate old, evolved component of water
- Indicates perched sample may be ~15 years old

Water stable isotopes

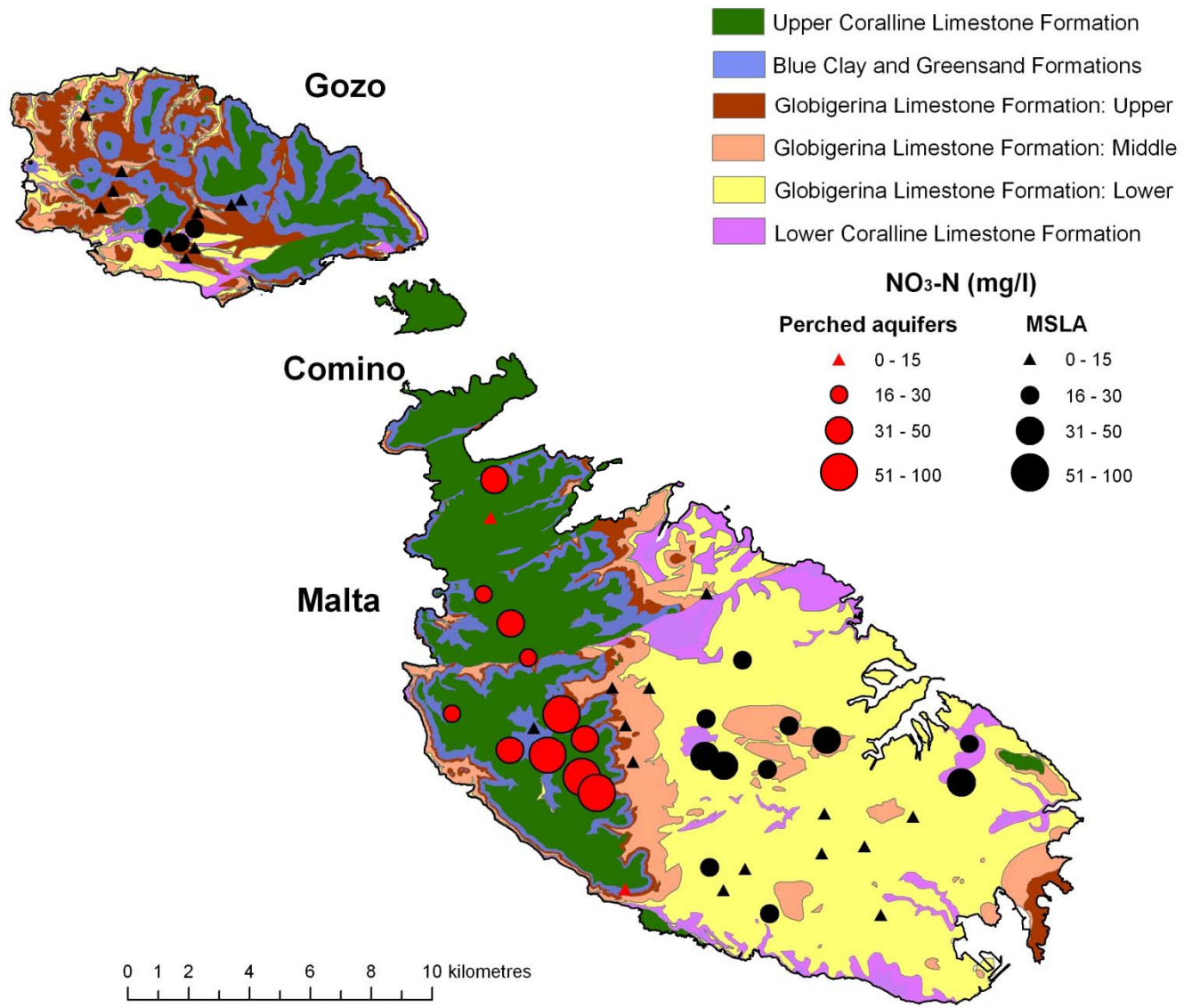


- Desalination peaked in 1995
- Some tap water is desalinated seawater
- Raw sewage and treated sewage effluent (TSE) show influence
- Evidence in groundwater
- Some groundwater <15 years old

Groundwater regimes

	Perched	Malta MSL	Gozo MSL
Semi-permeable cover	None	Part	Large part
Recharge	Direct	Direct & influenced by cover	Mainly influenced by cover
Depth to water table (m)	20 – 50	Variable – up to 190	Variable – up to 100
Unsaturated travel time	Days – years	Years – decades	Decades
Groundwater saturated zone age (years)	0 – 15	15 – 40	25 – 60

Nitrate-N distribution



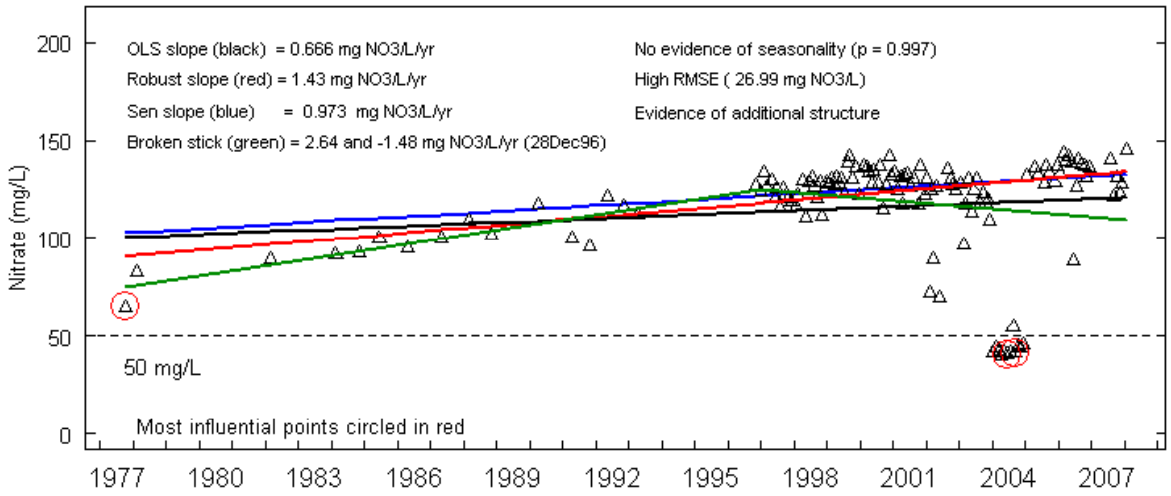
- Nitrate controlled by hydrogeological setting as well as landuse
- Gozo protected by low permeability cover

Conclusions

- Young water in perched aquifer in Upper Coralline limestone
- Water in the Lower Coralline sea level aquifers has a wide range of ages:
  - Residence time indicators, tritium and recharge/storage ratio all suggest saturated zone age of several decades
  - Aquifer properties data suggest possible unsaturated zone travel up to 100 years
  - Lack of coliforms suggest limited rapid routes from surface
  - Rapid water level response to rainfall and presence of modern desalinated water indicates some rapid routes
- Pollutant distribution influenced by hydrogeological setting

Implications

- Difficult to relate pollutants to present day land use
- Pollutants may be retained in porewater and moving slowly through the unsaturated zone providing a long-term source
- Management of water quality under the WFD difficult with these long timescales
- Studies of this type key to understanding future trends




From Stuart et al. 2010. Applied Geochemistry, **25**, 609-620